River Water Quality in Tāmaki Makaurau / Auckland

2020 Annual Reporting and National Policy Statement for Freshwater Management Current State Assessment

R Ingley, J Groom

February 2022

Technical Report 2022/2

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Research and Evaluation Unit | RIMU

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Kumeu River, photograph by R. Ingley (RIMU)
Cascades Stream at Waiheke Island, photograph by S. Benito (RIMU)

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 37 sites across the region using a range of variables to evaluate nutrient enrichment (toxicity and eutrophication), sedimentation and water clarity, metal contaminants, and indicators of faecal pollution. These key issues are influenced by point and diffuse source discharges, land and instream erosion, as well as natural and climatic variability.

The National Policy Statement for Freshwater Management (NPS-FM) 2020 National Objectives Framework (NOF) defines a number of compulsory attributes, and bands ranging from A to D (or A to E for *E. coli*) for those attributes to measure ecosystem health. This report focuses on the water quality component of ecosystem health. Not all compulsory attributes are currently monitored by Auckland Council. Work is underway to implement these additional requirements. This annual report also presents a summary of variation among sites within the 2020 calendar year, introduces two new monitoring sites, and analysis of additional water quality variables recently added to the programme.

The distribution of NOF bands for the current 2016-2020 assessment period was similar to the previous 2015-2019 period. Regionally there is a low risk of nitrate or ammonia toxicity effects to aquatic fauna even for the most sensitive species. There are localised issues where streams were found to fail national bottom lines in the Pukekohe/Franklin area (nitrate), and in some urban streams (ammonia). Adverse effects from nutrient enrichment can occur at concentrations far lower than nutrient levels that cause toxicity. A quarter of 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. This is a provisional grading that should be further calibrated against measured clarity for the region. 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. All urban and rural streams were in D or E bands. 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. Draft regional attributes have been proposed for metal (copper and zinc) toxicity. Several urban streams failed the proposed regional bottom line for zinc. Copper concentrations were elevated in urban and some rural streams, but no sites were below the proposed regional bottom line. These proposed attributes will be revised in the future.

Collectively, 29 per cent of monitored streams failed at least one national or proposed regional bottom line for water quality attributes (nitrate, ammonia, visual clarity, copper, or zinc). This included 55 per cent of urban sites, and 25 per cent of rural sites. More than 30 per cent of urban sites failed more than one bottom line. No sites with predominantly native or exotic forest in the upstream catchments failed these bottom lines.

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1 Introduction

Freshwater environments are valued by the people of Tāmaki Makaurau / 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).

Water quality is a core component of ecosystem health and also influences the aesthetics and many uses of water. The river water quality monitoring programme commenced in 1986. This information is used to understand the current state of water quality, and trends over time, to inform environmental management.

River water quality is currently monitored on a monthly basis at 37 streams across the region using a range of physical, chemical, and microbiological variables or attributes. These attributes focus on key issues including nutrient enrichment (eutrophication), sedimentation and water clarity, metal contaminants, and indicators of faecal pollution. These attributes can be affected by land use activities, point and diffuse source discharges, and land and instream erosion.

Rivers form the interface between land and sea, conveying land-based contaminants to our estuaries, harbours, and coasts, where they can accumulate and disrupt natural processes and functions. 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 are small in length, with most less than a few metres wide. Many 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). The topography of Tāmaki Makaurau 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, soft-bottomed rivers. High gradient rivers with hard stony substrates are mostly restricted to catchments that drain the Waitākere Ranges, Hunua Ranges and Aotea Great Barrier Island.

This report presents the current state of river water quality within Tāmaki Makarau including:

- A summary of the variability of water quality parameters within and between sites in the 2020 calendar year.
- NPS-FM 2020 National Objectives Framework – Describes the current state of rivers through the assessment of water quality parameters or attributes in relation to ecosystem health (water quality) and human health values.

A regional water quality index was used by Auckland Council to summarise water quality state in relation to ecosystem health prior to the introduction of the National Objectives Framework. The water quality index for river water quality assessment is being phased out but can be referred to in Appendix E.

This information on river water quality can be added to mātauranga Māori 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.

1.1 Programme objectives

Auckland Council's river water quality monitoring programme supports the following wider 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 state 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 NPS-FM National Objectives Framework

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 for rivers and lakes. Monitoring information is required in both the objective setting process and to monitor progress towards objectives through time.

The NOF includes four compulsory values of freshwater ecosystems, ecosystem health, human contact, threatened species, and mahinga kai. Other values may also be identified. There are five key components that contribute to ecosystem health, and several compulsory attributes are defined to describe the state of our freshwater environments.

This report focuses on the water quality component of river ecosystem health. Other compulsory attributes used to measure river ecosystem health are reported elsewhere. Not all compulsory attributes are currently monitored by Auckland Council and additional monitoring is planned, or in progress, to meet these information needs (see Table 1-1).

Table 1-1: Summary of NPS-FM 2020 NOF compulsory river attributes.

Freshwater type	Component	Attributes	Information
Rivers	Water quality	Ammonia (toxicity)	This report
	Water quality	Nitrate (toxicity)	This report
	Water quality	Dissolved oxygen	Monitoring initiated in 2021
	Water quality	Visual clarity	This report
	Water quality	Dissolved reactive phosphorus	This report
	Ecosystem processes	Ecosystem metabolism	In preparation
Wadeable Rivers	Aquatic life	Periphyton	Monitoring initiated in 2020
	Aquatic life	Fish Index of Biotic Integrity (IBI)	Monitoring to be initiated in 2022
	Aquatic life	Macroinvertebrate Community Index (MCI*/QMCI)	LAWA
	Aquatic life	MCI Average Score Per Metric (ASPM)	LAWA
	Habitat	Deposited fine sediment	Monitoring to be initiated in 2022
Rivers	Human contact	*E. coli*	This report

* Refer to TR 2021/05 (Chaffe, 2021) for further information on MCI

1.3 Supporting reports

This is the 31st annual report since the inception of the river water quality monitoring programme. Prior to 2000, the rivers streams and lakes and coastal water quality monitoring results were presented within combined reports.

For the most recent comprehensive trend analysis, please refer to *River water quality state and trends in Tāmaki Makaurau 2010-2019* (Ingley, 2021).

Previous annual data reports and supplementary data files relating to this report can be obtained from Auckland Council's Knowledge Auckland website www.knowledgeauckland.org.nz.

Water quality and ecology data, and attribute grades can also be viewed in an interactive platform at the national land air and water Aotearoa (LAWA) website:

www.lawa.org.nz/explore-data/auckland-region/river-quality/

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

2 Methods

Auckland's river water quality monitoring programme currently includes 37 sites. Each of the 37 sites is sampled monthly as part of five sampling runs undertaken by Auckland 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). Rangitopuni River is also monitored by NIWA and has been monitored by Auckland Council since 2016.

The programme has evolved over time, with sites added or removed according to varying regional management priorities.

2.1 Site locations

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.

Monitored site location details are outlined in Table 2-1. Sites are mapped in Figure 2-1.

A new monitoring site was established at a tributary of Whangapouri Stream at Paerata Rise development in 2019 to set a pre-development baseline. Development will occur within the upstream catchment over a 25 to 30 year period.

The monitoring site at Otaki Creek was discontinued in 2020 due to ongoing issues with saline influence at this location. No suitable upstream monitoring locations were identified for the Otaki Stream. A new monitoring site was established at Newmarket Stream in April 2020 to replace the Otaki Stream monitoring site.

Table 2-1: Current river water quality monitoring sites.

Site name	NZTM X	NZTM Y	Year started	REC Class*	Stream order (REC)	Catchment area (ha)
Avondale Stream	1750593	5912264	2012	WW_Low_SS	3	339
Cascades Stream (Waitakere)	1735592	5916401	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	1735809	5945031	2009	WW_Low_SS	5	6157
Kumeu River	1739288	5928785	1993	WW_Low_SS	4	4566
Lucas Creek	1751468	5934510	1993	WD_Low_SS	3	616
Mahurangi River (Forestry)	1747742	5965032	1993	WW_Low_SS	2	490
Mahurangi River (Warkworth)	1748863	5970459	1993	WW_Low_SS	4	4844
Makarau River	1736092	5953231	2009	WW_Low_SS	4	4834
Matakana River	1753506	5976494	1986	WW_Low_SS	4	1385
Newmarket Stream	1759154	5918649	2020	WW_Low_SS	3	624
Ngakoroa Stream	1775142	5881630	1993	WW_Low_VA	3	466
Nukumea Stream	1749409	5951379	2012	WW_Low_SS	2	99
Oakley Creek	1751965	5917602	1994	WW_Low_SS	3	1129
Okura Creek	1751403	5938704	2003	WW_Low_SS	3	553
Omaru Creek	1766048	5916759	2009	WD_Low_SS	2	515
Onetangi Stream	1786242	5926203	2013	WD_Low_HS	2	68
Opanuku Stream	1742162	5915566	1986	WW_Low_SS	3	1566
Ōtara Creek (South)	1767364	5907661	1985	WD_Low_VA	3	880
Ōtara Creek (East)	1768317	5908381	1992	WD_Low_SS	3	1828
Oteha River	1751328	5933522	1986	WD_Low_SS	3	1221
Botany Creek	1770718	5913018	1992	WD_Low_SS	3	665
Pakuranga Creek	1769474	5910902	1992	WD_Low_VA	2	216
Papakura Stream (Upper)	1774236	5902622	2012	WW_Low_HS	4	2324
Papakura Stream (Lower)	1771226	5900293	1993	WW_Low_HS	4	4716
Puhinui Stream	1766420	5904316	1994	WD_Low_SS	3	1304
Rangitopuni River	1744440	5932293	1986	WW_Low_SS	5	8366
Riverhead Stream	1737101	5933325	2009	WW_Low_SS	2	410
Vaughan Stream	1755413	5938727	2001	WD_Low_SS	2	239
Wairoa Tributary	1786762	5892804	2009	WW_Low_HS	2	227
Wairoa River	1782663	5901676	1986	WW_Low_HS	5	14885
Waitangi Stream	1754283	5878534	2009	WW_Low_VA	3	1897
Waiwera Stream	1748615	5953656	1986	WW_Low_SS	4	3023
West Hoe Stream	1748302	5950580	2002	WW_Low_SS	2	53
Whangamaire Stream	1763596	5884597	2009	WW_Low_VA	2	814
Whangapouri Stream	1768327	5887871	2019	WW_Low_VA	1	88

Figure 2-1: Location of the 37 river water quality monitoring sites. Area shaded in red shows the extent of urban area in 2019 (Hoffman, 2019).

2.2 Catchment land cover

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). 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).

A geospatial assessment of land cover 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 as of summer 2018/2019 were aggregated into broad level categories (Appendix A). 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 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 account for 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.

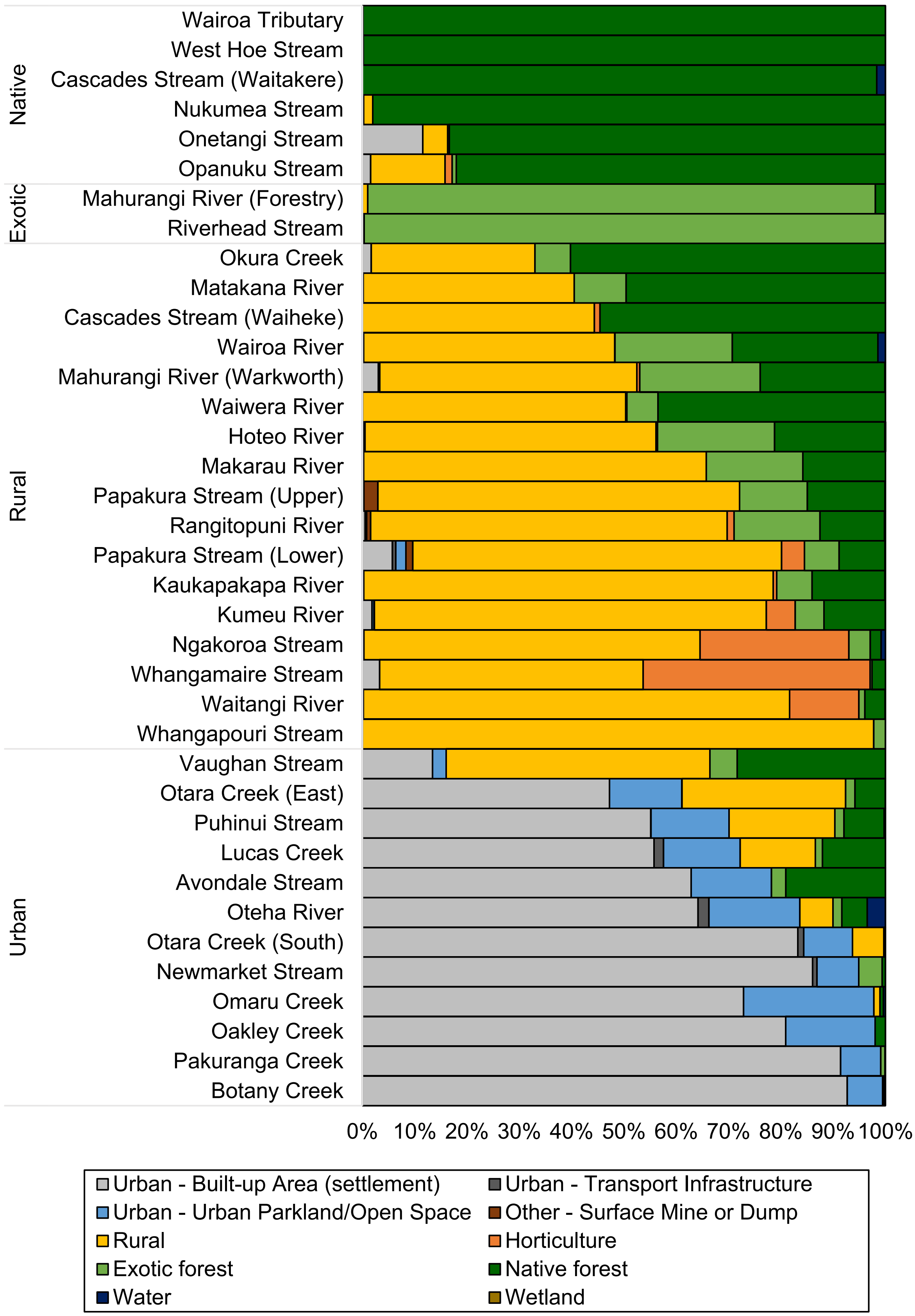


Figure 2-2: Summary of land cover in upstream catchments at 2018/2019 (LCDB5).

2.3 Data collection

The 37 sites are grouped into five sampling days which are undertaken within the same week each month. Sites are visited in the same order each time to ensure sampling occurs at approximately the same time of day each month for that site. A full list of the parameters measured is shown in Appendix 2.

All field practices were conducted according to RIMU's quality assurance procedures, 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.

Briefly, six measurements are obtained on site using an EXO sonde portable water quality meter. Bottles of water are then collected, chilled, and sent to RJ Hills Laboratories Ltd (Hills), an IANZ accredited laboratory for further analysis.

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 2020, and water quality index scores are presented here. NPS-FM NOF grading was undertaken for both NIWA and Council data for comparison. However for the purposes of presenting summary proportions of bands, only Auckland Council data for Rangitopuni Stream was included to avoid 'double counting' this site.

2.3.1 2020 COVID-19 impacts on monitoring

Water quality monitoring was suspended during Level 4 lockdown conditions (25th March-27th April). Monitoring was resumed during Level 3 conditions.

Consequently no samples were collected for streams within:

- the north-eastern area in March (West Hoe, Nukumea, Mahurangi Forestry, Mahurangi, Matakana, Okura, Vaughan, Lucas, and Oteha); and,
- the southern area in April (Papakura (upper and lower), Whangapouri, Whangamaire, Waitangi, Ngakoroa, Wairoa Tributary, Wairoa, Puhinui).

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 obtained from NIWA.

Prior to analysis, any data points that were assigned a quality assurance code of poor quality were removed from the dataset.

2.5 Data analysis

Two main forms of analysis of water quality are undertaken in this report.

- The range of values observed per site and water quality parameter within the 2020 calendar year.
- Grading against the NPS-FM 2020 national objectives framework (NOF) bands based on the five-year period 2016-2020.

Annual data is presented for 36 of the 37 sites. As a full year of data is not yet available at Newmarket Stream, further analysis cannot be undertaken. Minimum and maximum observations recorded between April 2020 to December 2020 are provided in supplementary data files only for this site. NOF grading is presented for 35 of the 37 sites as a minimum of five years of data is required for most attributes.

Water quality has also been summarised using the regional water quality index in relation to region-specific guidelines. This assessment has been undertaken based on the three-year period 2018-2020 and can be referred to in Appendix 5.

2.5.1 Censored data and substituted values

For some water quality parameters, censored values are used when true values are too low (below the detection limit), or too high (above the reporting limit) to be measured with precision by the analytical method being used by the laboratory.

Censored values were replaced by values half of the detection limit for annual statistics and box plots. Annual summary statistics are not presented in box plots where more than 50 per cent of the data for that site and parameter was censored (Larned et al., 2018).

Censored values were replaced by imputed values generated using ROS[1] for the purposes of calculating the five-year state statistics for NOF grading.

2.5.2 Annual data

Descriptive statistics for the 2020 calendar year are presented as box plots which show variation in the data. Box plots were produced using the software package R, using the default percentile functions. The boxes represent the inter-quartile range (25^{th} and 75^{th} percentiles) and the whiskers extend to the maximum, or minimum value within 1.5 times the inter-quartile range. Values beyond that range are plotted as outliers. The median is shown as a line within each box.

The y axis of some box plots is limited to enable the presentation of the range in data between sites, and the upper percentiles and outlier values are not all displayed. Refer to the summary statistics provided in supplementary data files for specific values.

2.5.3 NPS-FM National Objectives Framework current state

The 2020 current state is based on data for the five-year period 2016-2020 for all attributes (consistent with the recommendations of McBride, 2016).

Percentiles were calculated using the Hazen method. Statistics were compared to the relevant NOF or proposed regional attribute bands (Appendix C).

The overall band reflects the poorest of the different metrics for each attribute (e.g. median or 95^{th} percentile state).

2.5.3.1 Minimum data

The 2020 current state is based on data for the five-year period 2016-2020 for all attributes (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. A minimum of 90 per cent of samples at each site, for each attribute were required for analysis i.e. a minimum of 54 samples within the five-year assessment period. This is preferable to extending the period of assessment across different hydrological time periods.

Note that one reference site met the minimum 54 sample criteria but did not cover the fourth quarter of 2019 due to access issues. This site, Nukumea Stream, was included in grading analysis as the range of variation at the site is generally low and the samples collected are considered to adequately represent the site. One other site/attribute combination (DRP at Rangitopuni River (NIWA) also did not meet the standard with 53 samples available. However, the results were comparable to Auckland Council's monitoring of this site and therefore grading for DRP at this site was included in Appendix D. Only Rangitopuni River (Auckland Council) is included in section 4.2.

[1] Regression on Order Statistics; Helsel, 2012
[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.

2.5.3.2 Attributes

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. Nitrite and nitrate have been assessed separately since 2019 and are presented in the annual summary in Figure 4-4.

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, 2017) for comparison to NOF guidelines only.

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 Tāmaki Makaurau / 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. Further guidance is expected in relation to the suspended sediment (and deposited sediment) attribute from the Ministry for the Environment.

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

The regionally important attributes copper and zinc 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; Appendix C). Guidelines were not adjusted for water hardness or dissolved organic carbon (DOC). The guidelines, and modifiers are currently under review. Auckland Council has been gathering data on DOC and hardness since 2017, and 2018 respectively.

3 Annual Climate Summary

New Zealand's climate varies significantly from year to year and over the long-term. This is associated with decadal circulation and climate variations such as the Interdecadal Pacific Oscillation (IPO) and El Niño Southern Oscillation (ENSO).

These cycles affect prevailing winds and rainfall patterns. Variation in rainfall patterns influences changes in river flows, the use and abstraction of water, runoff of contaminants from land, erosion processes, and interactions between the stormwater and wastewater networks.

Rainfall over the period of November 2019 to April 2020 was approximately 52 per cent below the long-term regional average, the lowest recorded in the past forty years (Johnson, 2022). This resulted in severe meteorological drought in January and February 2020 with drought conditions easing in April to May (NIWA, 2019, NIWA, 2020). The 2020 mean annual low flows in rivers were the lowest on record for nearly 40 per cent of river flow monitoring stations spread across the region (Johnson, 2022). 2020 had the greatest number of low flow days in streams over the past forty years.

Twelve hydrology monitoring stations are paired with water quality monitoring sites, with a further five located nearby[3] water quality monitoring sites. Information from these sites is used to broadly characterise variation in river flows between years, between sites, and to identify notable high flow events that may explain observations of high concentrations of contaminants in these rivers. Water quality results are not flow adjusted.

Long-term flow conditions or flow duration curves (i.e. the range of flows that can be expected to occur at that river hydrology station[4]) were compared to the flow conditions experienced at that river hydrology monitoring station on the days that we undertook water quality monitoring during 2020.

Figure 3-1 summarises the range of flows that occurred at each of the selected hydrology stations, on the river water quality monitoring days in 2020, standardised by the per cent exceedance of flows compared to long term flow records. High percentile exceedance indicates **low flow** conditions i.e. 90 per cent of flows within that stream over time are higher than the flow recorded on that day. Low percentile exceedance indicates **high flow** conditions i.e. where only 10 per cent of flows are higher than the flow recorded on that day. Figure 3-1 shows that median flow levels were consistently above the 50% percentile, and for many sites, the boxes over topped the blue line demonstrating that conditions were representative of lower, long-term river flow conditions. For several streams, samples from February or March were obtained in conditions equivalent to the lowest flows recorded over the history of flow monitoring at that site (100 per cent exceedance).

[3] Located on the same stream but within approx. 1-2 km upstream or downstream.
[4] Based on the maximum data range available for the selected sites with a minimum of 10 years of records

The monitoring programme is not specifically designed to capture high river flow events. However, high flow events greater than the 10th percentile of flows were noted in August across most north-eastern and Tāmaki streams, and in July across southern streams. These were corroborated by field observations noting heavy rain in the preceding days.

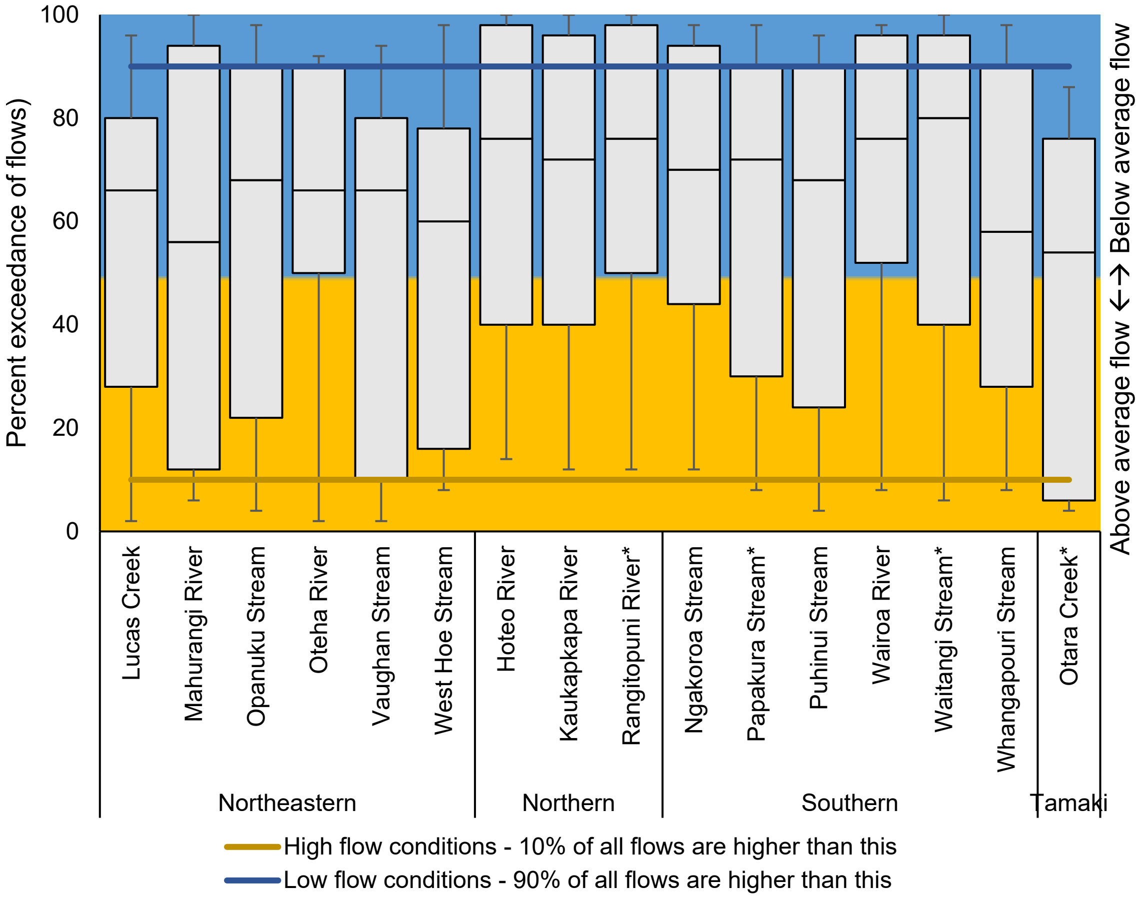


Figure 3-1: Range of river flows on water quality sampling days at paired or nearby flow sites.
Box plots show interquartile range and median, and whiskers show min-max flows. Sites noted with * are nearby water quality sites and not explicitly paired.

4 Results and Discussion

4.1 Annual data summary

Box plots, visually representing the spread in data, are provided in section 4.1.3 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 (as per Figure 2-2).

A high-level description of each of the parameters assessed is provided in Appendix B. Sites, and parameters that are new to the programme and this reporting series are outlined further in sections 4.1.1 and 4.1.2 respectively.

The range of values recorded for each parameter at each site during 2020 were similar to what has been reported for previous years. Generally lower total oxidised nitrogen, and turbidity, were observed this year, particularly in rural streams, which may reflect lower surface run off over the year (see section 3, Figure 4-1 to Figure 4-9 and supplementary data).

Monthly monitoring of dissolved oxygen is likely to underestimate minimum concentrations in streams as the diurnal minimum typically occurs in the early hours of the morning. Dissolved oxygen concentrations less than 4 mg/L are likely to indicate significant stress on aquatic fauna[5]. Summer dissolved oxygen concentrations fell below this level in thirteen streams in 2020, mostly in February and March, coinciding with the peak of the drought period.

Some notable results were recorded in 2020 including:

- Dissolved reactive phosphorus, and total phosphorus concentrations at Lucas Creek in January were an order of magnitude higher than the 98th percentile recorded at this site over the preceding 10 years. A visible plume was observed from an upstream tributary in dry weather conditions, indicating a possible pollution event had occurred upstream (pers. obs. D. Colella, RIMU). Elevated concentrations were also observed in August following heavy rain with a visible plume from the same tributary.
- Dissolved and total zinc concentrations at Pakuranga Creek in November were higher than the 98th percentile recorded at this site over the preceding 10 years. Metal concentrations were also elevated at Botany Creek, and Ōtara Creek in November, however this does not appear to coincide with rainfall or elevated flow.
- Total zinc concentrations at Mahurangi River (Forestry) in May were higher than the 98th percentile recorded at this site in the past 10 years. This coincided with heavy rain and elevated suspended sediments and high turbidity. Dissolved zinc concentrations remained below

[5] Based on the national bottom line for 1-day minimum concentrations NPS-FM 2020.

detection limits suggesting that high zinc concentrations were bound to sediments within the catchment.

4.1.1 New sites

Whangapouri Stream is predominantly within a rural pastoral landscape, but extensive urban development is planned within the upstream catchment. The stream is located within the Pukekohe specified vegetable growing nitrate exemption area but is not subjected to the pressures of horticultural production within the immediate catchment area. Interactions with groundwater are not well understood in this section of the stream.

Preliminary results from the 2020 annual reporting year indicate that this stream has the lowest pH and dissolved oxygen levels, and highest chlorophyll a concentrations of all monitored streams (see Figure 4-1, Figure 4-2, Figure 4-3). High turbidity, ammoniacal N concentrations, and *E. coli* levels were also observed. Collectively this suggests that water quality is likely to be considered poor within this stream, and subject to the effects of eutrophication.

Nitrate levels were more comparable with other rural streams across the region and are not in the same order of magnitude as the three other monitored streams in the Pukekohe specified vegetable growing area that are impacted by high nitrate levels. Phosphorus concentrations are also more comparable with other rural streams unlike the low phosphorus concentrations observed at the three other streams monitored within the Pukekohe area.

Newmarket Stream is predominantly within an urban, residential landscape. The stream channel is artificially lined with concrete at the monitoring site. Preliminary results will be available for this site from the 2021 reporting year.

4.1.2 New parameters – chlorophyll a, DIN, DOC, hardness

This is the first year that chlorophyll a, dissolved inorganic nitrogen (DIN), and the metal toxicity modifiers total hardness and dissolved organic carbon (DOC) have been included in annual reporting on river water quality.

Chlorophyll a is a green photosynthetic pigment in plants and algae and is used as a measure of algal (phytoplankton) biomass in the water column. Excess nutrients in a stream can cause nuisance levels of algae to grow which can reduce habitat availability and quality for fish and instream invertebrates; and increase the oxygen demand in streams over diurnal and seasonal cycles. Phytoplankton communities can also be influenced by river flows, shading, and grazing by zooplankton or other fauna.

Chlorophyll a levels in reference, native forest streams were typically below detectable concentrations (0.00005 mg/L) but ranged up to 0.0013 mg/L. Across rural and urban streams, chlorophyll a ranged from below detection to 0.087 mg/L with annual median concentrations ranging from 0.00019 to 0.0034 mg/L (Figure 4-3). The highest annual median concentrations were observed at Whangapouri Creek, Botany Creek, and Oteha River (0.0015 to 0.0034 mg/L). The maximum recorded concentrations were also observed at Botany Creek and Oteha River (0.087, 0.052 mg/L respectively).

Dissolved inorganic nitrogen is the sum of ammoniacal nitrogen, nitrate and nitrite nitrogen. In surface waters, most of the dissolved inorganic nitrogen is in the form of nitrate, and ammonia and nitrite are rapidly oxidised to nitrate. Therefore, higher levels of nitrite or ammonia often indicate localised inputs of wastewater or fertiliser.

Dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are generally considered to be the most bioavailable forms of nutrients for uptake by aquatic plants and algae.

Both DIN and DRP need to be considered to understand the trophic state of rivers, including their influence on aquatic fauna and instream periphyton. The relationships between periphyton and nutrients are complex and spatially variable. Further monitoring is underway through a targeted periphyton monitoring programme to support the development of instream nutrient targets to protect streams from the risks of eutrophication.

Guideline values for DIN were **not** confirmed and implemented in the NPSFM 2020 and therefore grading for this attribute has not been undertaken in this report. For reference, the proposed bottom line for DIN was >1 mg/L for median concentration and >2.05 mg/L for the 95th percentile. Over the past five years, five sites would fail the proposed bottom line. These were the three streams in the Franklin area that have also been identified as failing the national bottom line for nitrate toxicity, and two urban streams, Oakley Creek and Otara Creek South.

Dissolved organic carbon is a form of organic matter in streams that is a source of energy in stream food webs and consequently has an influence on stream ecosystem metabolism. The main sources of DOC are from the decay of leaf litter and macrophytes and algae and from leaching through organic rich soils (such as wetlands), or from the discharge of wastewater (Reitsema et al., 2018). Dissolved organic carbon includes humic substances that can be yellow or black in colour which can attenuate light and reduce water clarity (Bright and Mager, 2016).

Metals, particularly copper, adsorb to dissolved organic matter forming complexes that reduce the uptake and toxicity of metals in freshwater organisms (ANZ, 2018). Further guidance on revising copper toxicity guideline values accounting for DOC is currently in preparation (J. Gadd, NIWA, pers. comm).

DOC levels in the four reference, native forest streams[6] ranged from 0.5 to 4.9 mg/L with median concentrations between 0.9 and 2.3 mg/L (Figure 4-7). Across rural, and urban streams, DOC ranged from 0.85 to 14.5 mg/L with annual median concentrations ranging from 1.2 to 7.05 mg/L. The lowest annual median concentrations in rural and urban streams were across the three streams in the Pukekohe/Franklin area. The highest annual median concentrations were observed at Okura Creek, Vaughan Stream, and Rangitopuni River (6.6-7.05 mg/L). The highest maximum concentrations were observed at the two exotic forest sites Riverhead Stream, and Mahurangi Forestry ((12.6-14.5 mg/L), and at Lucas Creek (14.2 mg/L).

[6] Excluding native forest sites Onetangi Stream and Opanuku Stream due to >10% urban or rural land use.

Total water hardness is the sum of calcium and magnesium concentrations as calcium carbonate in the water. These compounds generally originate from the weathering of rocks and soil. Water containing calcium carbonate at less than 60 mg/L is generally considered 'soft', 60-120 mg/L 'moderately hard', and 120-180 mg/L 'hard' (WHO, 2011). Most New Zealand waters are considered to be soft (MoH, 2018).

The majority of the monitored streams in the Auckland region were found to have 'soft' water. Water hardness in reference, native forest streams ranged from 17.2 to 50 mg/L with median concentrations of 25 to 42 mg/L (Figure 4-8). Fourteen of the 37 streams were found to have annual median concentrations in the 'moderately hard' range. One stream, Pakuranga Creek, had hard water with an annual median concentration of 149 mg/L.

The proposed regional zinc toxicity guidelines are based on the ANZ 2000 guidelines at a standard hardness of 30 mg/L. The toxicity of zinc generally decreases as water hardness increases and it is noted that most monitored streams typically have harder water than 30 mg/L. However, the adjustment of zinc toxicity to account for water hardness, and consideration of other modifying factors including pH and dissolved organic carbon is currently under review (J. Gadd, NIWA, pers. comm). Until the new guidelines are released it is difficult to predict the effect of these changes on the final guideline values i.e. the revised guidelines may be lower or more conservative, but after accounting for bioavailability they may be less conservative (Gadd et al., 2019).

4.1.3 Annual Summary Box Plots

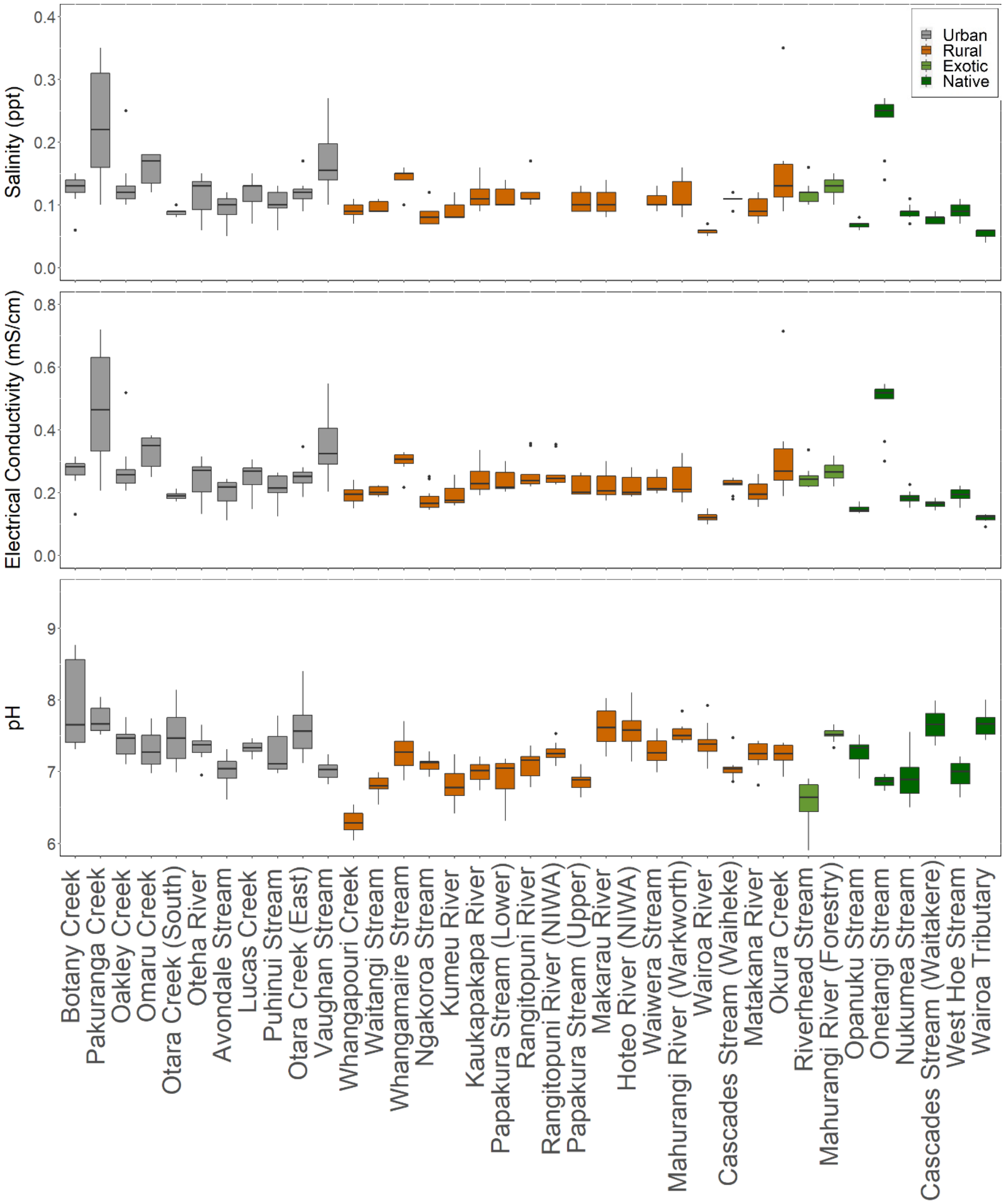


Figure 4-1: Variation in salinity (ppt), electrical conductivity (mS/cm), and pH for river water quality data collected from January to December 2020.

One outlier value for salinity and conductivity is not displayed for Omaru Creek (0.48 ppt, and 0.97 mS/cm)

One outlier value <6.0 pH units is not displayed for Whangapouri Creek (5.6).

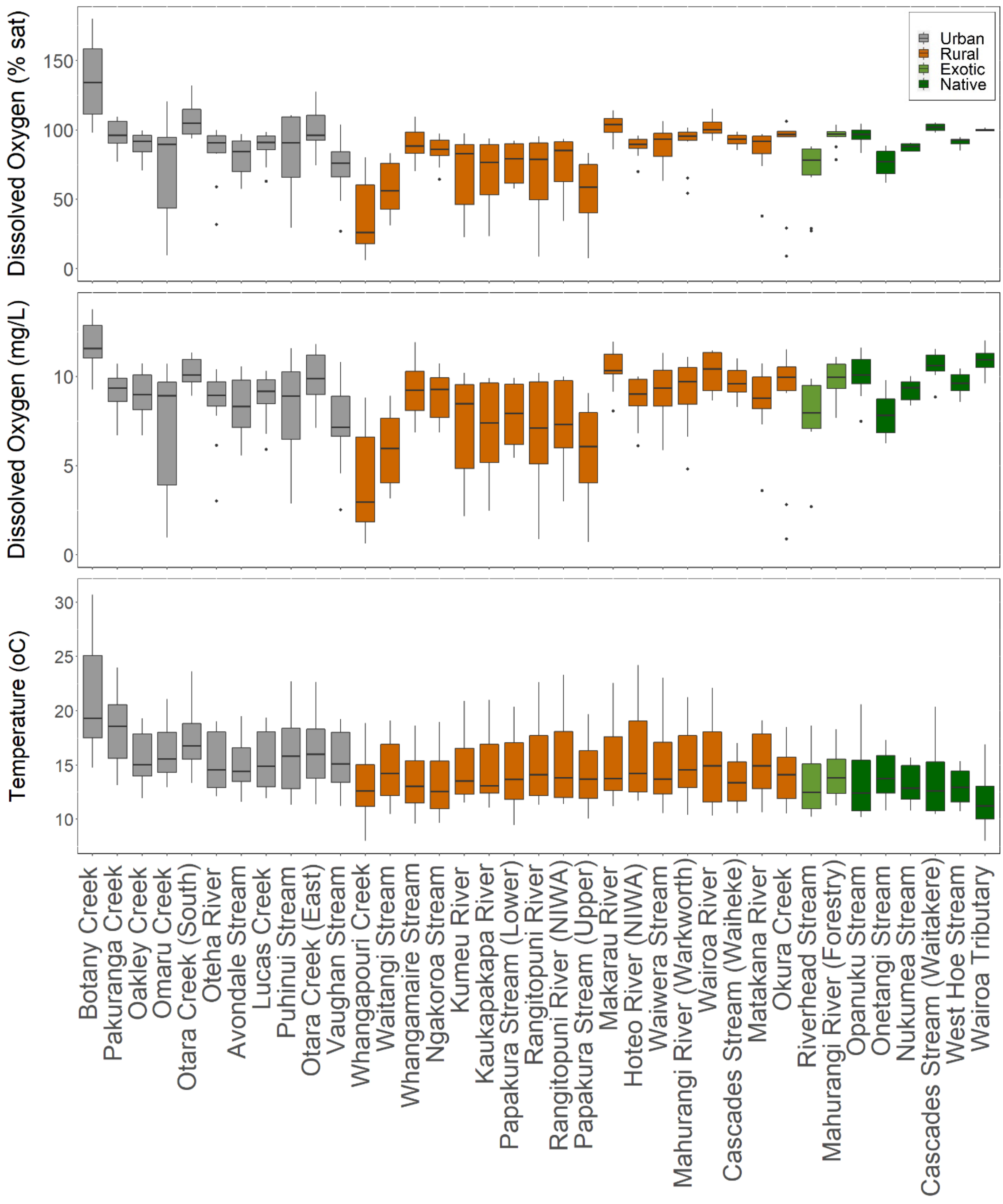


Figure 4-2: Variation in dissolved oxygen as % saturation and concentration (mg/L) and temperature (°C) for river water quality data collected from January to December 2020.

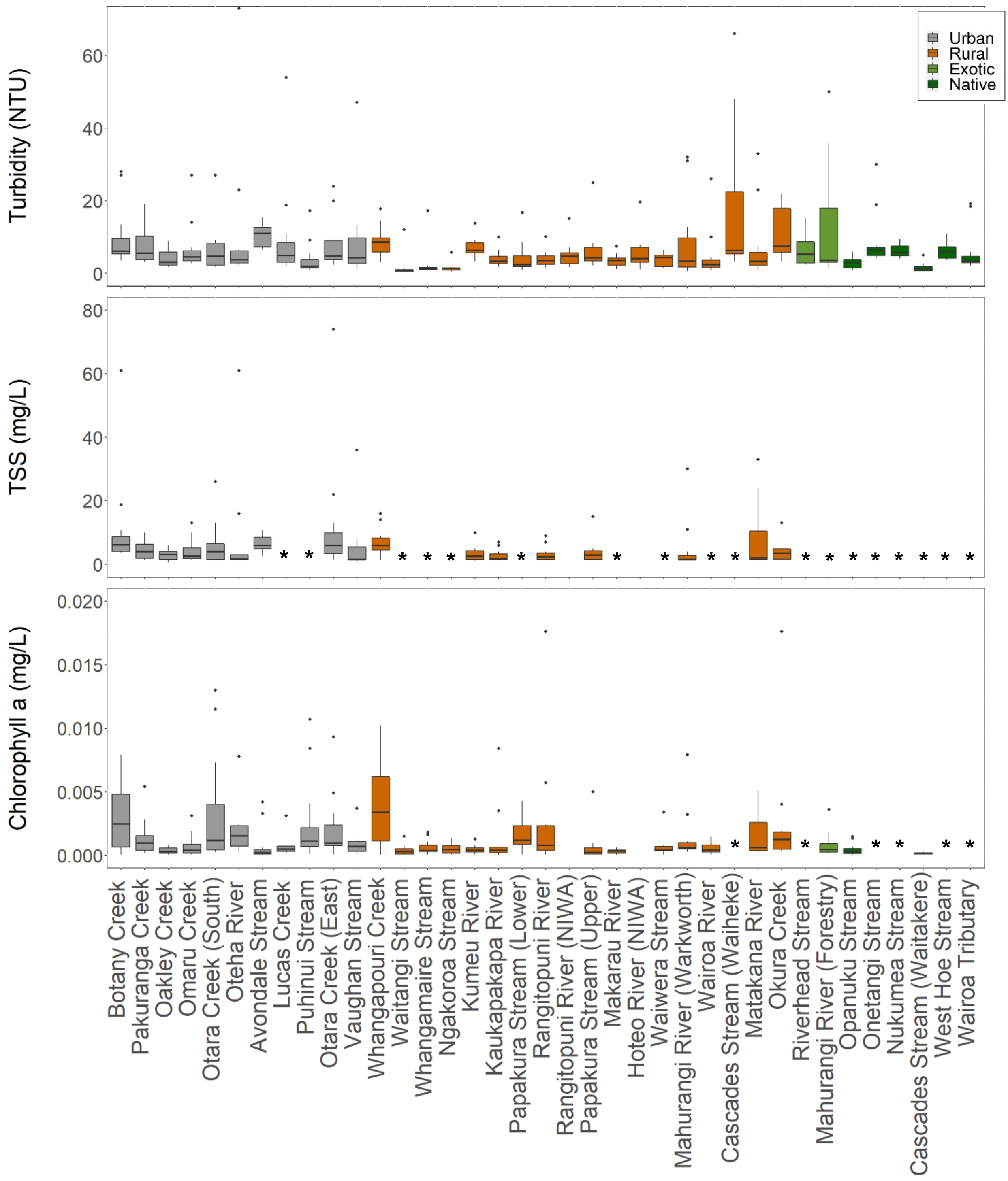


Figure 4-3: Variation in turbidity (NTU), total suspended solids (mg/L), and chlorophyll a for river water quality data collected from January to December 2020.

* = >50 per cent of values below detection limit

Three outlier values >70 NTU are not displayed including, Cascades (Waiheke) (87 NTU), Okura Creek (86 NTU), and Ōtara (East) (77 NTU). One outlier value for TSS >80mg/L is not displayed: Ōtara (East) of 98 mg/L in August.

These outliers all coincided with high rainfall. Three outlier values for Chlorophyll a >0.02 mg/L are not displayed including two instances at Botany Creek (0.042,0.087 mg/L), and Oteha River (0.052mg/L).

TSS, and chlorophyll a are not assessed by NIWA at Rangitopuni River or Hoteo River.

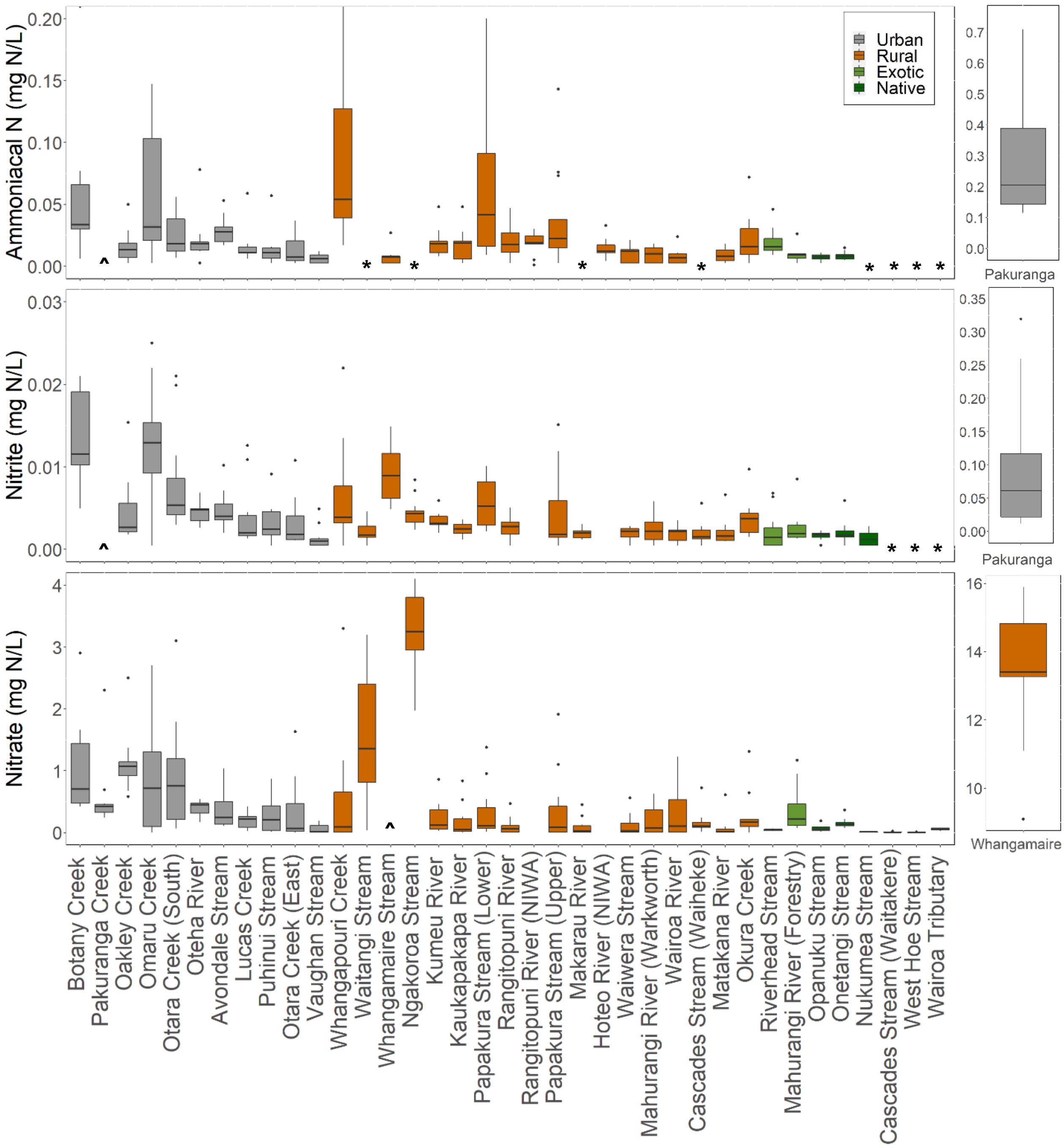


Figure 4-4: Variation in ammoniacal N (mg/L), nitrite (mg/L), and nitrate (mg/L) for river water quality data collected from January to December 2020.

^ = see inset

* = >50 per cent of values below detection limit

Four outlier values for ammoniacal N, and the upper whisker for Whangapouri Creek >0.2 mg/L are not displayed. See maximum values for Ōtara Creek (South), Whangapouri Creek, and Botany Creek in supplementary data tables.
Three outlier values for nitrate and the upper whisker for Ngakoroa Stream >4 mg/L are not displayed. See maximum values for Ngakoroa Stream and Omaru Creek in supplementary data tables.

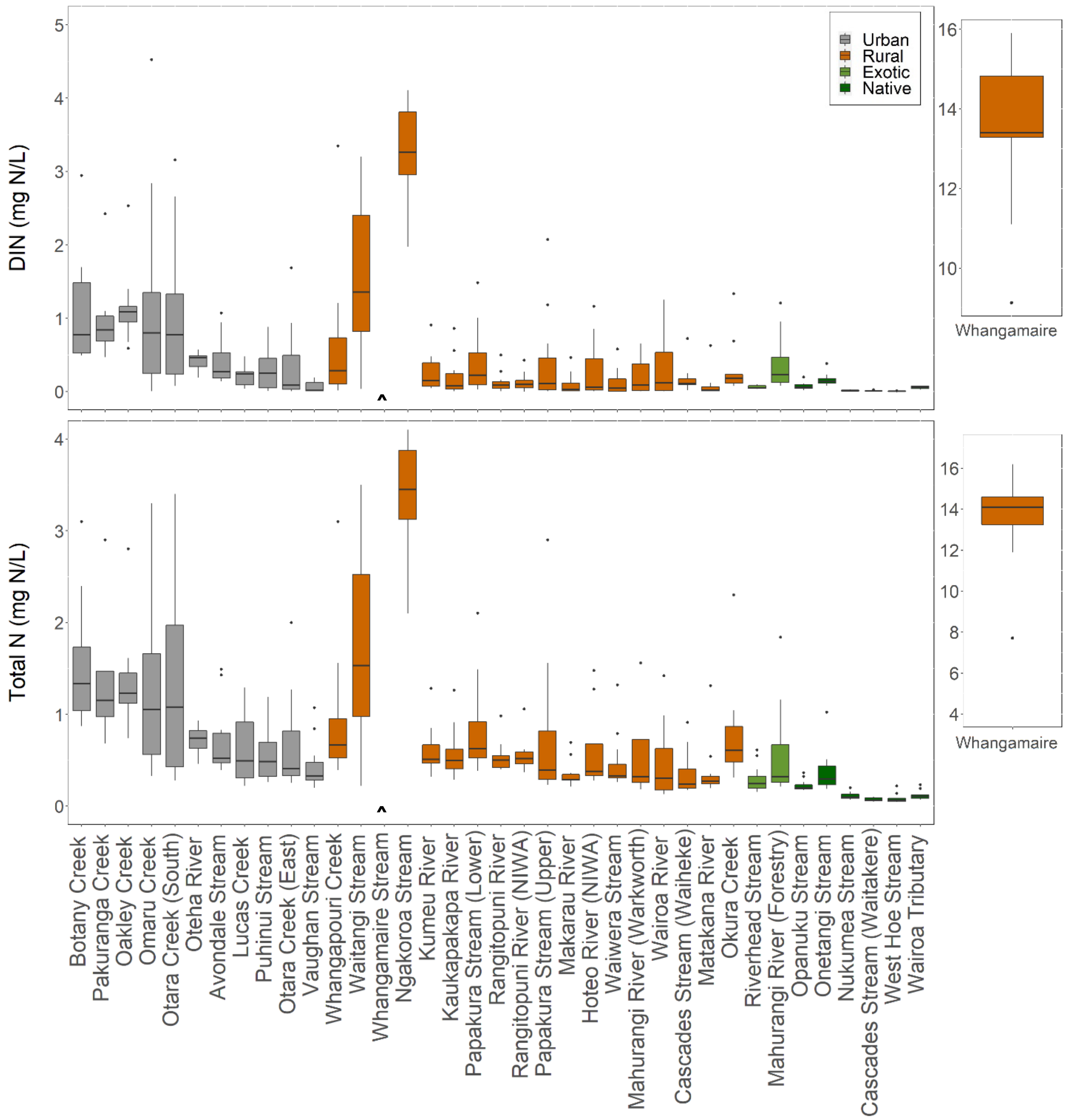


Figure 4-5: Variation in dissolved inorganic nitrogen (mg/L), and total nitrogen (mg/L) for river water quality data collected from January to December 2020.

Two outlier values for DIN >5 mg/L are not displayed. See maximum values for Ngakoroa Stream.

One outlier value for total N, and the upper whisker for Ngakoroa Stream >4 mg/L is not displayed. See maximum values for Ngakoroa Stream and Omaru Creek in supplementary data tables.

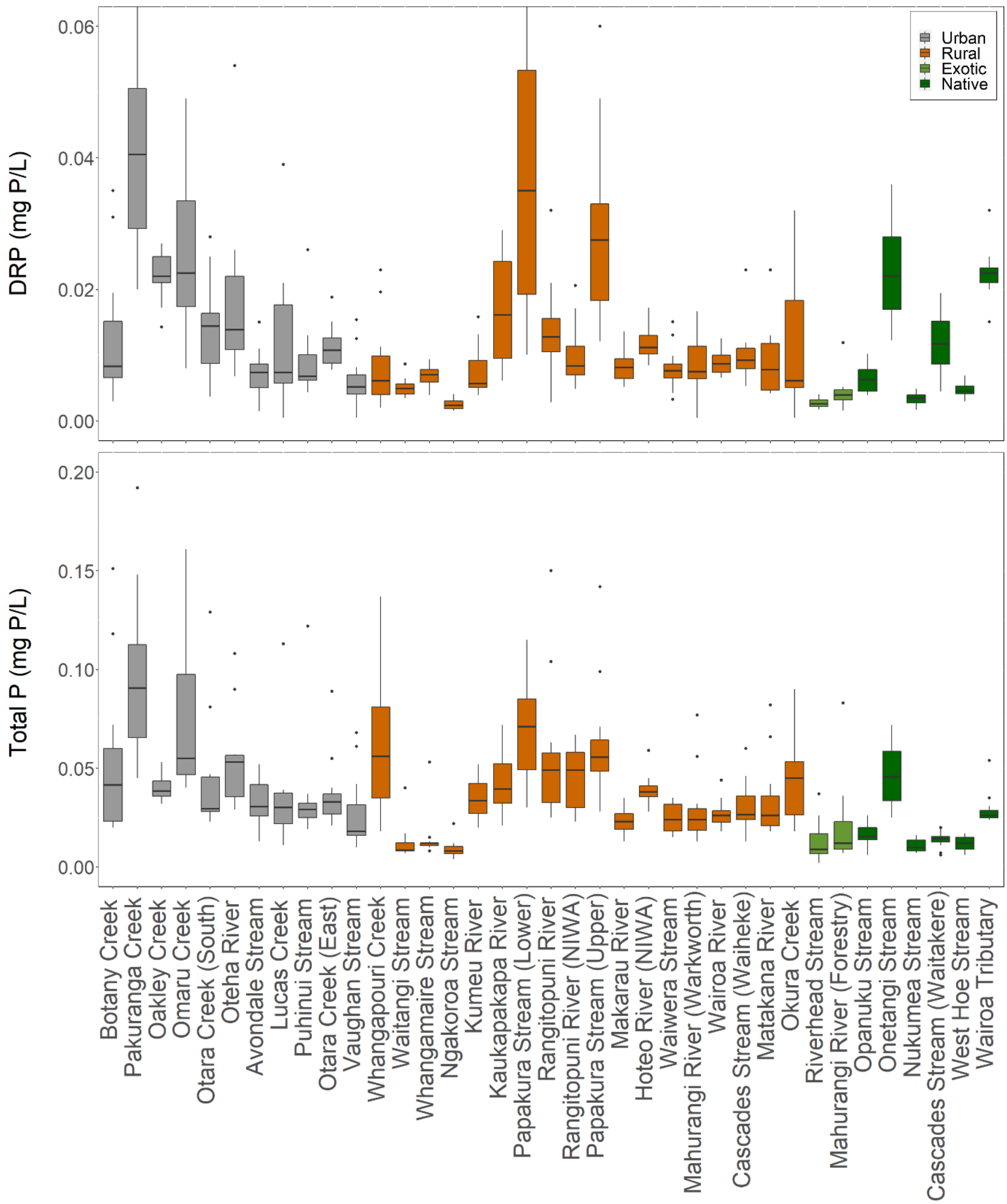


Figure 4-6: Variation in dissolved reactive phosphorus (mg/L) and total phosphorus (mg/L) for river water quality data collected from January to December 2020.

One outlier value for DRP (Lucas Creek), and the upper whisker for Papakura Stream (lower) >0.06 mg/L are not displayed. See maximum values in supplementary data tables.

Three outlier values for total phosphorus >0.2 mg/L are not displayed. See maximum values for Waiwera Stream, Lucas Creek, and Rangitopuni River (NIWA) in supplementary data tables.

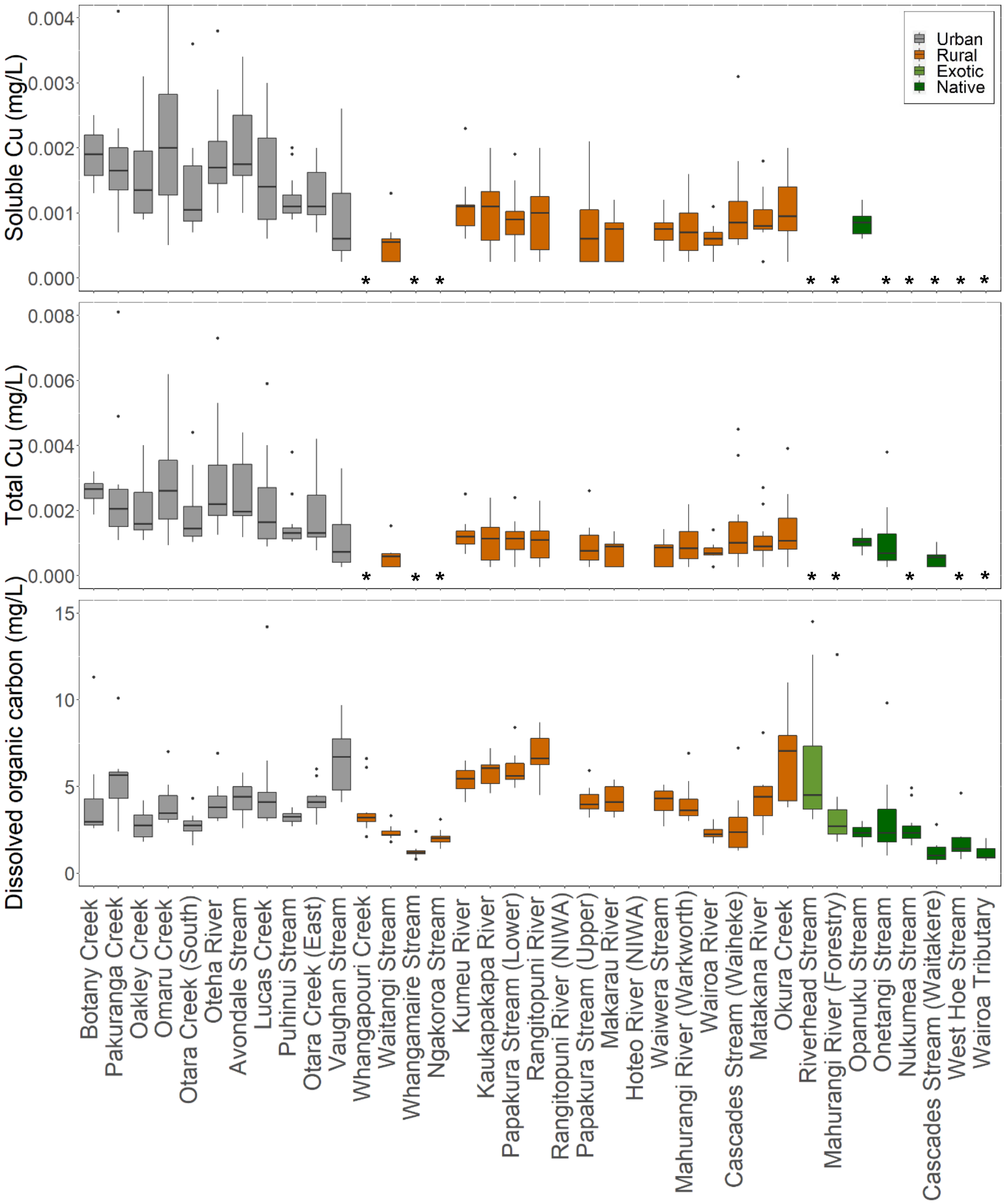


Figure 4-7: Variation in soluble copper (mg/L) and total copper (mg/L) and dissolved organic carbon (mg/L) for river water quality data collected from January to December 2020.

* = >50 per cent of values below detection limit

Two outlier values for soluble copper (Botany Creek, Pakuranga Creek), and the upper whisker for Omaru Creek >0.004 are not displayed. See maximum values in supplementary data tables. One outlier value for total copper is not displayed for Botany Creek (0.0148 mg/L)

Metals and DOC are not assessed by NIWA for Rangitopuni River or Hoteo River.

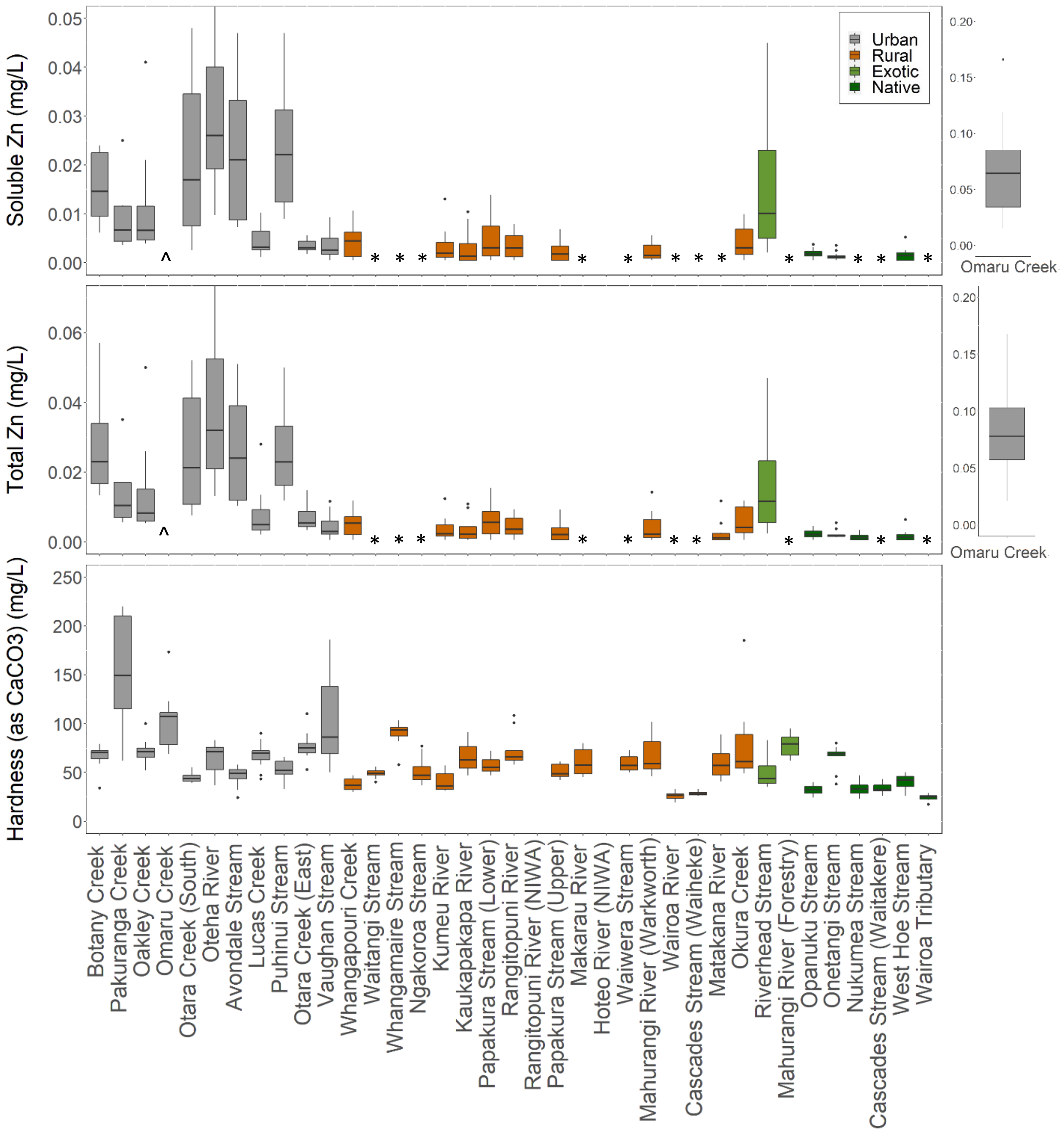


Figure 4-8: Variation in soluble zinc (mg/L) and total zinc (mg/L), and total hardness (mg/L) for river water quality data collected from January to December 2020.

^ = see inset

* = >50 per cent of values below detection limit

Four outlier values for soluble zinc, and the upper whisker for Oteha River >0.05 mg/L are not displayed. See maximum values for Pakuranga Creek, Botany Creek, Ōtara Creek (East), and Oteha River in supplementary data tables.

Five outlier values for total zinc and the upper whisker for Oteha River >0.07 mg/L are not displayed. See maximum values for Pakuranga Creek, Botany Creek, Puhinui Stream, Oteha River, Redwood Stream, Ōtara Creek (East) in supplementary data tables.

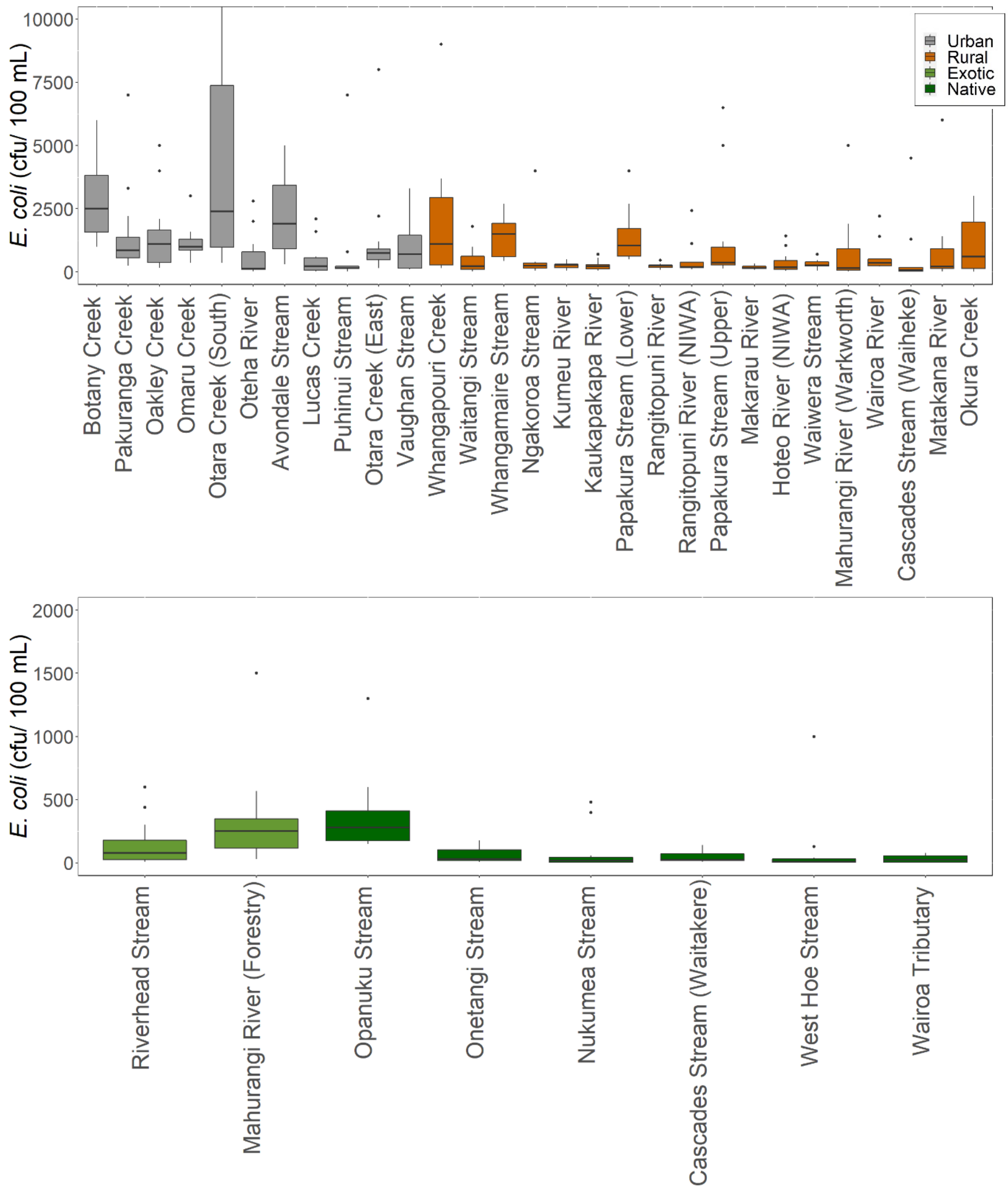


Figure 4-9: Variation in *E. coli* (cfu/100mL) for river water quality data collected from January to December 2020.

Seven outlier values >10,000 cfu/100 mL are not displayed across a total of six sites in urban or rural areas. See maximum values in supplementary data tables.

Three outlier values >2000 cfu/100 mL are not displayed including two instances at Onetangi Stream (3700,2200 cfu/100mL following heavy rain), and Wairoa Tributary (3100 cfu/100 mL)

Note: *E. coli* analysed by NIWA at Hoteo River and Rangitopuni River is reported in MPN/100 mL but are considered to give comparable results.

4.2 NPS-FM 2020 National Objectives Framework current state assessment

Water quality data for the five-year period 2016-2020 was assessed against the attribute metrics in the National Objectives Framework (NOF) in the NPS-FM (2020) (see Appendix C) and reported as the relevant band for each monitored stream site for 2020. Bands range from A to D for most attributes, and A to E for *E. coli*. The 'National Bottom Line' refers to the minimum state for some attributes which varies from D band for DRP and suspended sediment, to C and D band for nitrate and ammonia toxicity. It is important to note that this assessment does not yet include all compulsory attributes relating to water quality and our understanding of ecosystem health will continue to develop as more information is gathered (as outlined in section 1.2).

Where aspects of water quality are below a national bottom line, this means that there are high concentrations of that contaminant in the waterway, and these are the most at risk of adverse effects on the health of aquatic fauna, including fish and macroinvertebrate communities[7].

The overall bands for each attribute (water quality parameter) and provisional grades for metals (Gadd et al., 2019), are summarised across the region (Figure 4-10), and per dominant land cover class (Figure 4-11). The overall bands per stream site are mapped in Figure 4-12. Bands for the individual metrics (median, 95th percentile etc.) per stream site and attribute are reported in table form in Appendix D

The distribution of grades for the 2016-2020 assessment period was similar to the 2015-2019 period. The overall proportion of monitoring sites in each band was similar between these rolling periods (see revised state and trends Ingley 2021). Collectively, over 80 per cent of monitored sites had elevated *E. coli* levels demonstrating widespread potential human health risk across all rural and urban streams.

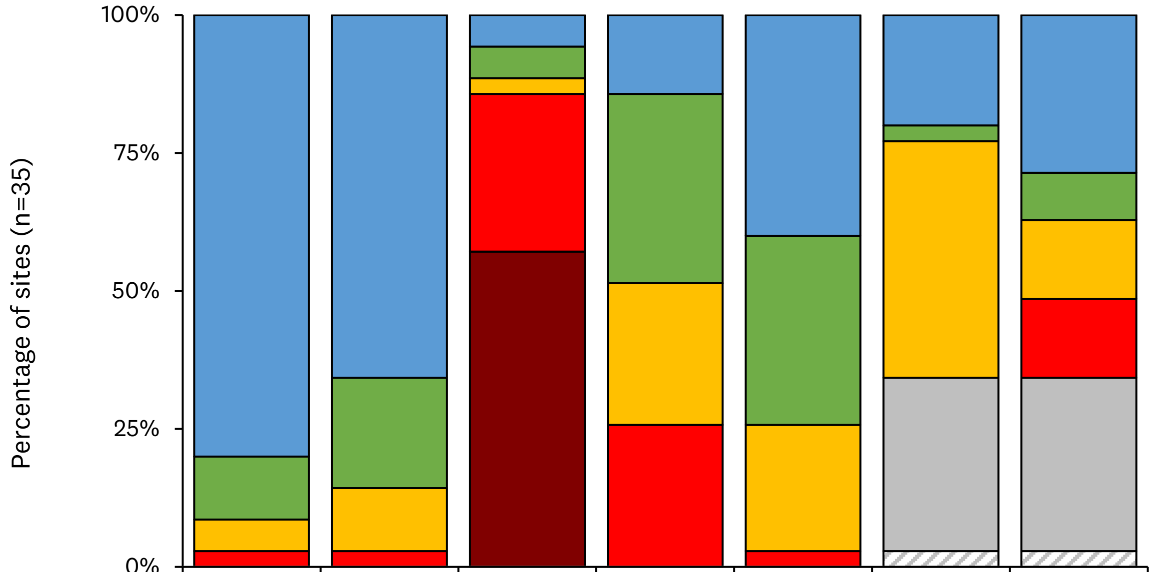
There was a higher proportion of streams assessed as bands A and B for DRP than the previous rolling period (Ingley, 2021). Regionally, there is a low risk of nitrate or ammonia toxicity effects even for the most sensitive species, except within streams to the south in the Pukekohe/Franklin area (nitrate), and infrequently due to episodic events in some urban streams (ammonia). Adverse effects of nutrient enrichment can occur at concentrations far lower than nutrient levels that cause toxicity. Further assessment of periphyton community responses to instream nutrient concentrations (DRP and DIN) will improve our understanding of the trophic state of rivers.

Only one monitored site was below the national bottom line for suspended fine sediment (visual clarity), however, nearly a quarter of monitored sites were in band C where sensitive native fish species may be lost. Suspended fine sediment grading is considered to be provisional as visual clarity was calculated based on measured turbidity and further regional calibration of turbidity against measured visual clarity is recommended.

[7] Unless existing natural conditions are identified to explain the band grading.

Grading of metal toxicity is currently based on a subset of 23 monitoring sites, including all eleven urban streams, nine of 16 rural streams, both exotic, and one reference site. Additional monitoring of metals was added at the remaining sites from July 2018 (except for NIWA monitored Hoteo River which is noted as 'Not Assessable'). A minimum of five years of monthly data is required to grade these additional 10 rural and native forest sites. These are recorded as 'insufficient data' in Figure 4-10 however, interim grades[8] are provided in Figure 4-11.

The addition of these interim grades further demonstrates that metal contamination is primarily an issue within urban streams. Fourteen percent of all sites failed the proposed regional bottom line, with a further 14 per cent in band C. All of these were urban streams except for one exotic forest site that was also found to have elevated zinc levels. All urban streams, and some rural streams were in band C for copper contamination. Interim grading also places one reference headwater stream in band C. In rural streams, the C band for copper was primarily based on the 95th percentile metric indicating more episodic risk, whilst in urban streams, the C band also reflected the median state.



	Nitrate (TON)	Ammonia	E. coli	DRP	Clarity (turbidity)	Copper	Zinc
A	80%	66%	6%	14%	40%	20%	29%
B	11%	20%	6%	34%	34%	3%	9%
C	6%	11%	3%	26%	23%	43%	14%
D	3%	3%	29%	26%	3%	0%	14%
E			57%				
Insufficient data						31%	31%
Not assessed						3%	3%

Figure 4-10: Proportion of sites within each overall band for NPS-FM 2020 NOF water quality attributes, and proposed Auckland specific regional attributes (copper and zinc) (2016-2020). Red shading in table = bands below national bottom line or proposed regional bottom line.

[8] Based on a minimum of 30 samples over July 2018 to December 2020.

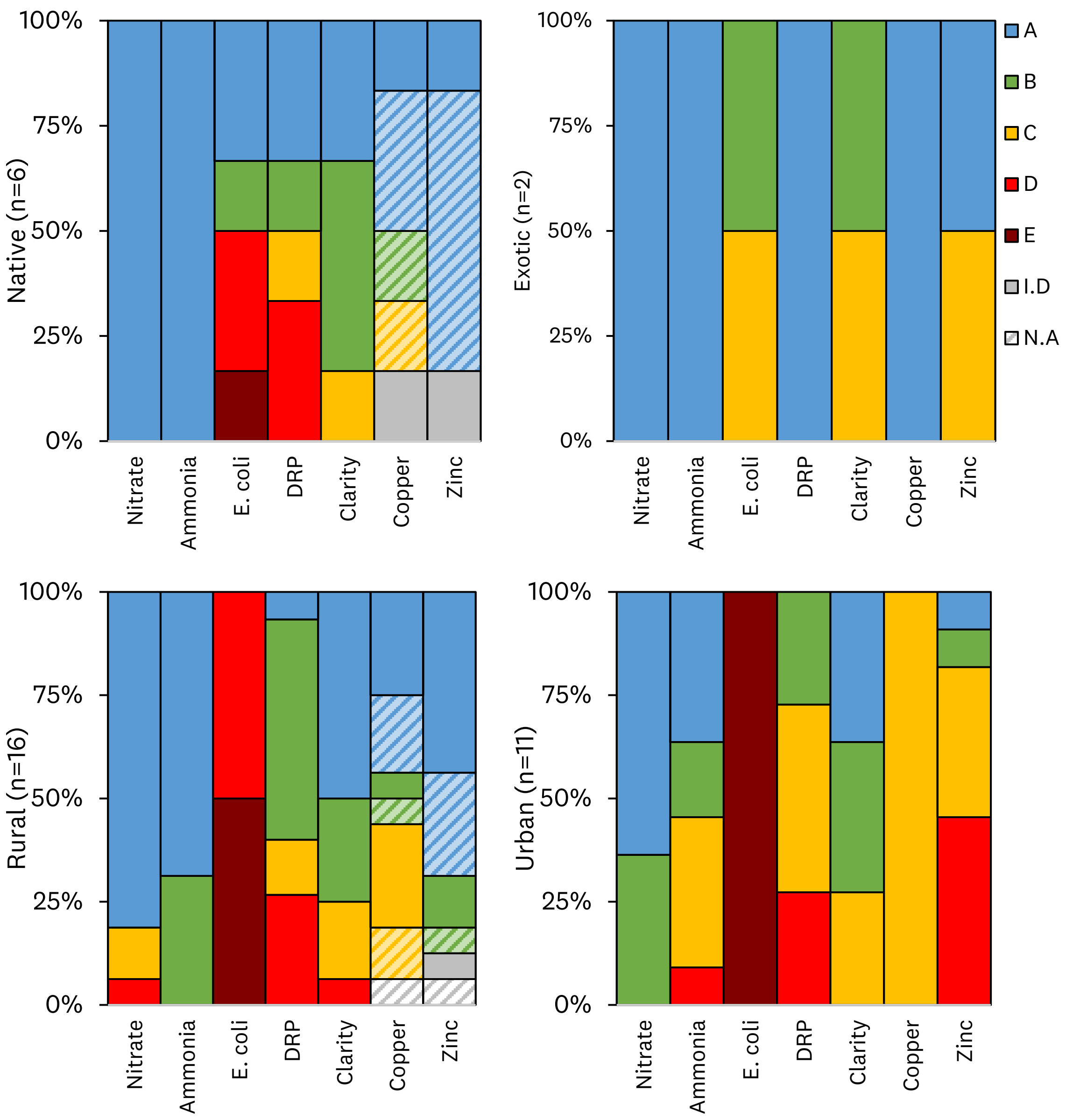


Figure 4-11: Proportion of sites within each overall NPS-FM 2020 band per dominant land cover class (2016-2020). Note striped boxes reflect interim grades based on 2018-2020 only.

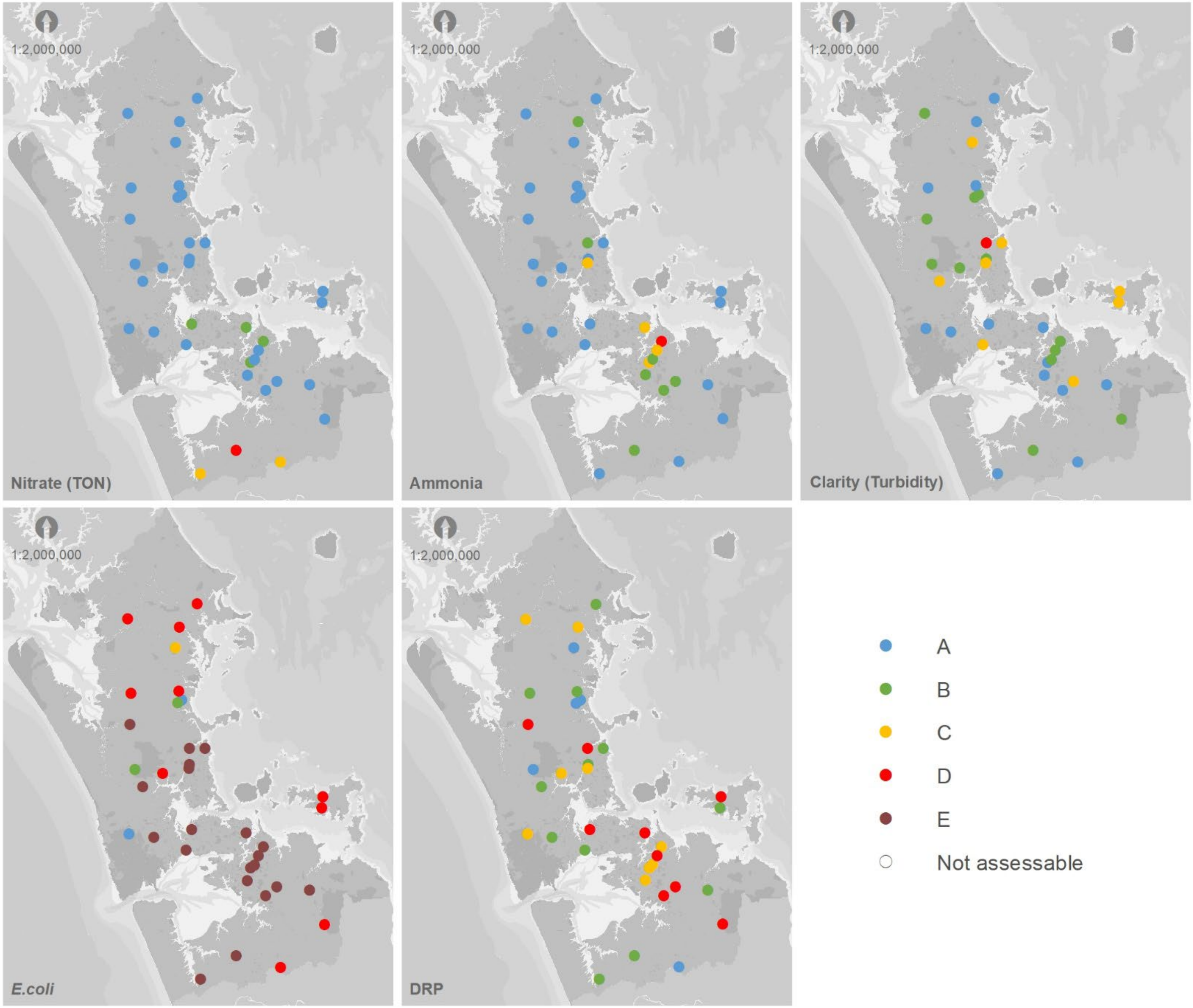


Figure 4-12: Tāmaki Makaurau / Auckland region summary maps of current state (2016-2020) for NPS-FM 2020 overall NOF attribute grade per site.

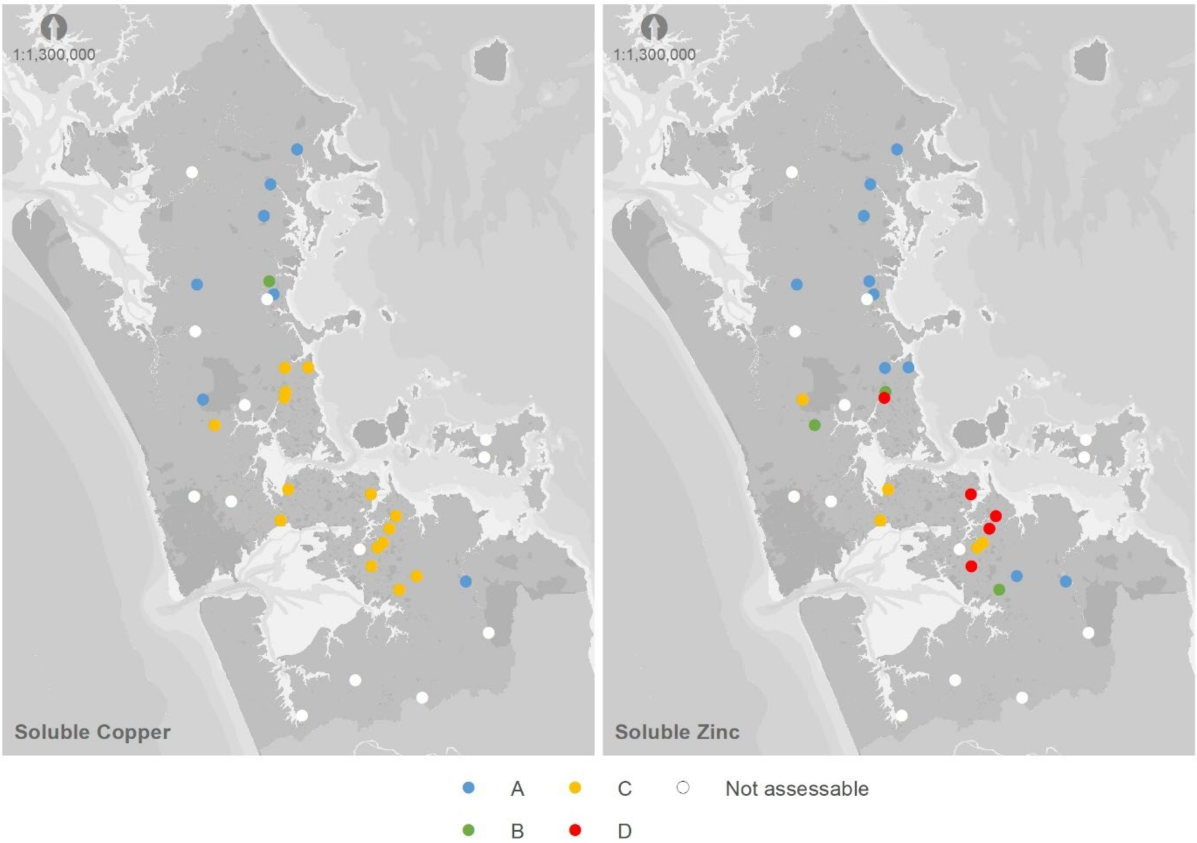


Figure 4-13: Tāmaki Makaurau / Auckland region summary maps of current state (2016-2020) provisional grades for proposed regional copper and zinc guidelines.

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[9] (Figure 4-10).

Three rural sites in the Franklin area (Ngakoroa Stream, Whangamaire Stream and Waitangi Stream) fail the national bottom line for nitrate toxicity (Figure 4-11). 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). Further research is underway to better characterise groundwater and surface water interactions in this area. These three sites have the highest proportion of horticultural land cover of all monitored sites (see Figure

[9] 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 (see Figure 3-5 and Ingley, 2020 for further evidence on the relative proportions of nitrate and nitrite).

2-2). Two of the monitored Franklin sites, were graded C. This indicates potential adverse effects on growth for 20 per cent of sensitive species (i.e. fish) may be expected. Whangamaire Stream was graded D, which signals that impacts on the growth of multiple instream species can be expected.

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 for the next 10-year period.

Four urban streams are in the B band for nitrate toxicity, Oakley Creek, Omaru Creek, Ōtara Creek (South), and Botany Creek. Only one of these streams, Oakley Creek is within this range for the median metric as well as the 95th percentile (Appendix D). This suggests that nitrate concentrations are more consistently elevated at this site compared to occasional events. Botany Creek declined in overall grade from A band in the 2015-2019 rolling assessment period.

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.

4.2.2 Ammonia toxicity

Regionally, over 80 per cent of sites are above the national bottom line for ammonia toxicity (Figure 4-10). All five streams that failed the national bottom line were in urban areas (see Appendix D). However, four of these streams (Botany Creek, Omaru Creek, Ōtara Creek (South), Oteha River) only failed the bottom line due to one-off maximum value exceedances recorded within the 2016 to 2020 period, if the 95th percentile were compared to the maximum attribute band metrics none of these streams would fail the nation bottom line. This suggests that infrequent effects of ammonia toxicity occur instream in some years. Only Pakuranga Creek failed the national bottom line based on the median state of ammonia concentrations observed at this site. The high nitrite concentrations also recorded at this site (and able to be reported for the first time here) indicate that there is likely a nearby point source discharge impacting this monitoring site. Targeted investigation of discharges from the upstream catchment is currently underway.

Botany Creek was the only monitored stream graded as 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 band assessment is calculated; this site will remain in the D band until 2025 reporting as a result of this event. The second highest concentration observed at this site within the past five years would fall within the C band (April 2016).

4.2.3 *E. coli*

The assessment of *E. coli* as a faecal indicator bacteria undertaken here is based on monthly routine monitoring and 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 4-10, Figure 4-11).

All eleven monitored urban streams were in the lowest band, E, where more than 30 per cent of the time, there is an estimated five per cent risk of infection (Figure 4-11). These streams were in the lowest band across all four metrics except for Puhinui Stream which was in the D band for the median state (Figure 4-14, and Appendix D).

Half of the 16 monitored rural streams were also in the lowest band, E. Four of these were in band E across all four metrics (Whangamaire Stream, Papakura Stream (upper) and Papakura Stream (lower), and Okura Creek) (Figure 4-14, and Appendix D). The predominantly native forest site Opanuku Stream was also graded E (Figure 4-11) across all metrics. This stream is influenced by rural land use with >10 per cent of the upstream catchment dominated by this land use type.

The other eight monitored rural streams were graded D where there is an estimated five per cent risk of infection 20 to 30 per cent of the time (Figure 4-11). One monitored stream, Cascades at Waiheke was graded D based on the 95th percentile metric with the other measures generally falling across the C grade (Figure 4-14, and Appendix D). The predominantly native forest site, Onetangi Stream was also graded D based on the 95th percentile metric (Appendix D). This stream is influenced by residential land use, covering over >10 per cent of the upstream catchment. Wairoa Tributary is entirely within native forest but was graded D in this rolling period compared to B in the previous rolling period due to an increase in the 95th percentile with all other metrics remaining in the A or B band. Mahurangi River at Forestry was the only site graded C with all other native and exotic forest sites in bands A and B.

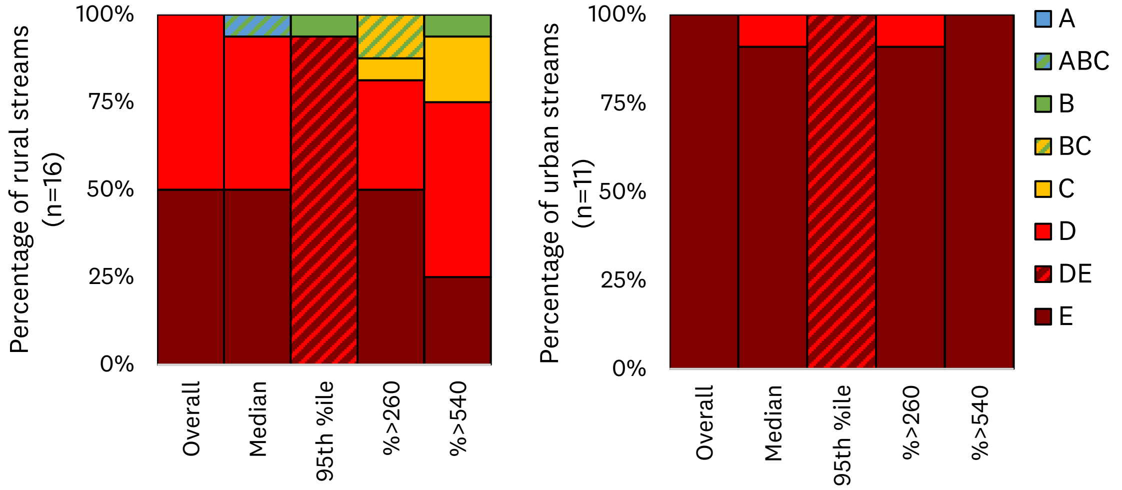


Figure 4-14: Summary of the proportion of sites within each band across *E. coli* NPS-FM 2020 NOF metrics for rural (left) and urban (right) streams.

4.2.4 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.

Overall, 25 per cent of monitored streams were in band D including urban, rural, and native forest streams. A further 25 per cent were in band C. Further work is necessary to contextualise the DRP band assessment with regard to what may be considered normal/background DRP concentrations for the region. It is also necessary to consider phosphorus and nitrogen concentrations together to understand nutrient responses and influences on instream aquatic plants and periphyton.

A considerable change in the proportion of monitored streams in bands A and B was observed between the 2015-2019 and current assessment periods. Nearly 50 per cent of monitored streams were assessed to be in bands A and B compared to less than 30 per cent in the previous period (Ingley, 2021). This is driven by a change in the median metric from band C to band B across six rural and one urban stream monitoring sites. A change in median metric was also observed at two reference sites from band B to band A.

This change in attribute state is generally consistent with widespread improving trends in dissolved reactive phosphorus observed for the period 2010-2019, however this may be influenced by changes in the laboratory analytical method (Ingley, 2021).

4.2.5 Suspended fine sediment/visual clarity (turbidity)

The suspended fine sediment attribute is based on visual clarity and provides for measured turbidity to be converted to clarity (see section 2.5.3.2). Regional calibration of this conversion against measured visual clarity (black disc or clarity tube) is recommended to be undertaken and further guidance on this is anticipated to be released by the Ministry for the Environment by early 2022. Band assessment based on converted turbidity data is considered to be provisional at this stage. The 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 assessment of high sediment loads experienced relatively infrequently at any of these monitored sites[10]. This assessment also divides streams into specific classes based on aggregations of 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.

Only one stream, Okura Creek, failed the national bottom line (band D) for visual clarity (when converted from turbidity). It is noted that median concentrations of dissolved organic carbon are relatively high at this site (Figure 4-7) and that coloured humic substances can affect turbidity measurements (Bright and Mager 2016). It is recommended that further consideration is given to the effect of variation in water colour on instream turbidity and visual clarity and potential sources of organic matter.

Eight streams were assessed as band C compared to 10 streams in 2019. The two streams that changed grade were Ngakoroa Stream and Whangamaire Stream. Both of these streams are categorised as suspended sediment class 1 which has a much narrower range between bands. Consequently these streams are likely more susceptible to movement between bands over time.

[10] Event based sediment monitoring is undertaken across predominantly rural catchments within Auckland to inform sediment load modelling and management (Hicks et al. 2021)

4.2.6 Proposed Auckland specific attributes (metals)

4.2.6.1 Copper

The assessment of copper toxicity will change in future reporting with regard to upcoming revision of the ANZ guidelines, and consideration of toxicity modification by dissolved organic carbon (DOC) (Warne et al., 2018; Gadd, et al., 2019).

No sites were below the proposed regional bottom line (band D) for dissolved copper. All eleven monitored urban sites were in band C (Figure 4-11). Seven of these were in band C for both the median and 95th percentile metrics. Three urban sites (Ōtara Creek (South and East) and Puhinui Stream) were in band B for the median attribute, and one urban stream (Vaughan Stream) remained in band A for the median state (see Table 2-1).

Of the sixteen rural sites, nine have been graded previously and this year, an interim grade[11] has been calculated for an additional six rural stream monitoring stations. Metals are not monitored at Hoteo River. Most rural streams were in band A but 38 per cent of sites were in band C. Namely, Kumeu River, Okura Creek, and Papakura Stream (Lower and Upper), and interim grading for Rangitopuni River, and Cascades Stream (Waiheke). This grading was driven by the 95th percentile metric. Kumeu River and Papakura Lower were in band B based on the median metric while all others were in band A for the median state. Interim grading for Kaukapakapa River was also in band B for the median state. Interim grading for the three Franklin/Pukekohe streams was in band A. Both monitored streams dominated by exotic forestry were in band A.

One native forest stream was graded previously (Nukumea Stream). This year, an interim grade has been calculated for an additional four monitoring sites. West Hoe Stream did not meet the minimum data requirements. Collectively, three streams were in band A including Nukumea Stream, Wairoa Tributary, and Onetangi Stream. Cascades Stream Waitakere was in band B and Opanuku Stream was in band C due to the 95th percentile metric.

4.2.6.2 Zinc

The assessment of zinc toxicity will change in future reporting with regard to upcoming revision of the ANZ guidelines, and consideration of toxicity modification for instream water hardness (Warne et al., 2018; Gadd et al., 2019).

Nearly half of the eleven monitored urban sites were below the proposed regional bottom line for dissolved zinc (D band, Figure 4-11). At these sites, toxicity could approach acute levels (i.e. risk of death for sensitive instream species). This was due to the 95th percentile metric except at Omaru Creek which was also graded D based on the median state. One urban stream (Ōtara Creek (South)) changed from band D to band C when compared to the previous reporting period driven by lower concentrations at the 95th percentile.

[11] Based on min of 30 samples. Collected July 2018-Decmeber 2020. See Appendix C.

Of the sixteen rural sites, nine have been graded previously and this year, an interim grade[11] has been calculated for an additional five rural stream monitoring stations. Kaukapakapa River did not meet the minimum data requirements and metals are not monitored at Hoteo River.

Collectively, all rural streams were within bands A and B, suggesting there would be no, or minimal zinc toxicity effects observed. All five interim grades were in band A.

Riverhead Stream (exotic forest) was within band C based on the 95th percentile attribute. The other predominantly exotic forestry site was in band A. One native forest stream was graded previously (Nukumea Stream). This year, an interim grade was calculated for four of the five other monitoring sites[12]. Collectively, all five streams with predominantly native forest catchments were in band A.

[12] West Hoe Stream did not meet the minimum data requirements.

5 Summary

This report provides an annual summary of water quality across the regional river water quality monitoring network. This 2020 report introduced two new sites to the network as well as four new parameters that will improve our ability to understand river trophic state, and metal contamination in time.

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 2016-2020. It is important to note that this assessment does not yet include all compulsory attributes relating to water quality. Our understanding of ecosystem health will continue to develop as more information is gathered particularly in relation to the effects of nutrient enrichment on periphyton, and dissolved oxygen concentrations.

Nitrate and ammonia can be toxic to aquatic fauna at high concentrations. For most of the region, little or no toxicity risk is expected, even for the most sensitive instream species (>80 per cent of sites graded A or B). However there are localised issues. Three rural stream sites in the Pukekohe/Franklin area failed the national bottom line for nitrate toxicity. This is an established issue associated with intensive horticultural production in the catchment, and high concentrations of nitrate in the underlying shallow aquifers. Five urban stream sites (out of eleven) failed the national bottom line for ammonia toxicity, although this was primarily due to episodic events resulting in high maximum concentrations.

Nearly 50 per cent of monitored streams were assessed to be in bands A and B for dissolved reactive phosphorus compared to less than 30 per cent in the previous rolling assessment period. This change in grading is consistent with widespread improving trends in dissolved reactive phosphorus. However, this may have been influenced by changing laboratory analytical methods. Nearly a third of monitored streams had elevated DRP concentrations (band D) however there were no clear land cover or spatial patterns. Further research is necessary to contextualise the DRP band assessment in relation to natural variability within Auckland’s waterways, and trophic responses to nutrient enrichment such as periphyton abundance.

Visual clarity was assessed based on turbidity data via a national regression equation approach. This is a provisional grading that should be further calibrated against measured clarity for the region. Nearly a quarter of our monitored streams 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. There was no clear land cover influence, streams within rural, urban, and exotic forestry dominated catchments had similar proportions of sites in the different state bands. Only one stream failed the national bottom line (band D).

All monitored urban streams were the in band E, the poorest condition under NPS-FM 2020 criteria for *E. coli*. Half of the monitored rural streams were within the D band with the other half in the E band, generally following a pressure gradient with greater proportions of rural land use within the catchment. 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.

Two key metal contaminants were assessed in relation to chronic (long-term exposure) toxicity risk for river fauna. Interim grading was included for 10 additional sites this year providing better representation of the wider Auckland region. Metal contamination was primarily a risk for urban streams. Nearly half of the monitored urban sites were below the proposed regional bottom line for zinc toxicity which indicates potential acute toxicity effects could also occur in these streams. No sites were below the proposed regional bottom line for copper toxicity. However, all urban sites were in band C for copper toxicity. While zinc concentrations were typically low in monitored rural streams, nearly 40 per cent of rural sites were in band C for copper toxicity. This demonstrates that copper contamination is also a potential risk in rural streams. This risk of metal toxicity impacts will be reviewed following the revision of guidance on toxicity modifying factors for both copper and zinc.

Collectively, 29 per cent of monitored streams failed at least one national or proposed regional bottom line for water quality attributes (nitrate, ammonia, or metal toxicity, or visual clarity). This included 55 per cent of urban sites, and 25 per cent of rural sites. More than 30 per cent of urban sites failed more than one bottom line. No sites with predominantly native or exotic forest in the upstream catchments failed these bottom lines. Faecal contamination of rivers as indicated by *E. coli* is the most widespread issue facing Tāmaki Makarau / Auckland across urban, and rural streams.

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Appendix A. Contributing catchment information

Table A-1: 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 B. Physio-chemical parameters

Table B-1: Summary of river water quality parameters, detection limits, analytical methods and two sources of data collection.

Parameter	Unit	Detection limit	Method	Source
Dissolved oxygen	ppm	0.1	EXO2 Sonde (Xylem Analytics)	Field
Dissolved oxygen saturation	% sat	0.01	EXO2 Sonde (Xylem Analytics)	Field
Temperature	°C	0.01	EXO2 Sonde (Xylem Analytics)	Field
Conductivity	mS cm	0.01	EXO2 Sonde (Xylem Analytics)	Field
Salinity	ppt	0.2	EXO2 Sonde (Xylem Analytics)	Field
pH	pH units	0.01	EXO2 Sonde (Xylem Analytics)	Field
Total suspended solids	mg/L	3 1*	APHA (2017) 2540 D	Lab
Turbidity	NTU	0.05	APHA (2017) 2130 B (modified)	Lab
Chlorophyll a	mg/L	0.0002	APHA (2017) 10200 H (modified)	Lab
Nitrate nitrogen (NO_3N)	mg/L	0.001	Calculation ((NO3N+NO2N) – NO2)	Lab
Nitrite nitrogen (NO_2 N)	mg/L	0.001	APHA (2017) 4500-NO2 I (modified)	Lab
Total oxidised nitrogen (NO2N + NO3N)	mg/L	0.001	APHA (2012) 4500-NO3 I (modified)	
Ammoniacal nitrogen (NH_4-N)	mg/L	0.005	APHA (2012) 4500-NH3 H (modified)	Lab
Total Kjedahl nitrogen (TKN)	mg N/L	0.01	Calculation: TN – (NO3N + NO2N)	Lab
Total nitrogen (TN)*	mg N/L	0.01	APHA (2017) 4500-N C & 4500 NO3 I (modified)	Lab
Dissolved reactive phosphorus	mg/L	0.001	APHA (2017) 4500-P G	Lab
Total phosphorus*	mg/L	0.004	APHA (2017) 4500-P B & E (modified)	Lab
Dissolved copper	mg/L	0.0005	ICP-MS trace level. APHA (2017) 3125 B	Lab
Total copper	mg/L	0.00053	ICP-MS trace level. APHA (2017) 3125 B / US EPA 200.8	Lab
Dissolved zinc	mg/L	0.001	ICP-MS trace level. APHA (2017) 3125 B	Lab
Total zinc	mg/L	0.0011	ICP-MS trace level. APHA (2017) 3125 B / US EPA 200.8	Lab
Total Hardness	mg/L	1 mg/L as CaCO3	Calculated from calcium and magnesium.	Lab
Dissolved calcium	mg/L	0.05	ICP-MS trace level. APHA (2017) 3125 B	Lab
Dissolved magnesium	mg/L	0.02	ICP-MS trace level. APHA (2017) 3125 B	Lab
Dissolved non -purgeable organic carbon	mg/L	0.3	APHA (2017) 5310 C	Lab

- *From October 2020*

Table B-2: Summary of parameters assessed.

Parameter	Description
Salinity and Conductivity	Salinity levels increase as the influence of saline water increases i.e. in the lower parts of some streams where water becomes brackish. Salinity levels affect the toxicity of some contaminants. Electrical conductivity reflects the total ionic content of the water which is affected by the presence of dissolved salts such as chloride, nitrate, nitrite, phosphate, sodium, magnesium, calcium etc.
Temperature	Surface water temperature is primarily driven by seasonal and diurnal changes in solar radiation. The size of the water body and level of overhead shading affect the degree of influence of solar radiation i.e. small shallow unshaded waterways are warmed faster than deep well shaded waterways. The extent of catchment imperviousness also influences stream temperature where stormwater runoff passes over heated impervious surfaces (roads, roofs, etc). Temperature affects biological processes and moderates the toxicity of contaminants.
pH	pH is a measure of acidity/alkalinity. The geology and source of water often determines the pH of a stream. Alkalinity reflects the buffering capacity or how resilient the pH is to change. Diurnal cycles of photosynthesis and respiration can influence pH in streams with a high plant or algal biomass with maximum pH values typically occurring in the late afternoon, and minimum values in the early morning. pH affects biological processes and moderates the toxicity of contaminants.
Dissolved Oxygen (DO)	Oxygen is released by plants during photosynthesis and taken up by plants, animals and bacteria for respiration. Oxygen can also be transferred from the air to water particularly in areas of turbulence such as waterfalls or over riffles. Oxygen-scavenging compounds associated with organic matter also affect DO levels. High DO values can reflect high primary production while low DO values can reflect high rates of decomposition of organic matter. Reduced dissolved oxygen levels can affect the growth and reproduction of aquatic organisms. In extreme cases low DO levels due to respiration and/or chemical uptake can stress or kill aquatic organisms i.e. reduce the life-supporting capacity of the water. DO levels are diurnally and seasonally variable. DO is typically higher during the day and decreases at night. The concentration of dissolved oxygen at 100 % saturation in water is influenced by temperature, salinity, and atmospheric pressure. Colder waters hold more oxygen than warmer water.
Turbidity Suspended solids	Turbidity is a measure of the degree to which light is scattered in water by particles, such as sediment and algae. Total suspended solids are a measure of the amount of suspended material in the water column such as plankton, non-living organic material, silica, clay and silt. These variables are usually closely correlated but can vary where tannins or other coloured compounds can increase turbidity but are not associated with solid particles. The main potential sources of river transported sediment are sheetwash and hill erosion (hillslope erosion), mass wasting (e.g. landslides, earth flows etc.), gully erosion and stream bank erosion. The relative contribution of these sources depends on catchment geology, slope, rainfall, land cover, and the history of land use. Large quantities of sediment are mobilised during periods of land cover transitions (deforestation, urban development).

Parameter	Description
	Sediment is a primary stressor in many river environments. Excess deposited, or suspended fine sediment can reduce habitat quality, food resources, and reduce reproductive success of aquatic fauna. Terrestrial sediments transported to the coast may also cause estuary infilling, contribute to mangrove expansion, smother biota and habitats, clog gills and impede the feeding of aquatic organisms.
Nitrite (NO_2), Nitrate (NO_3) Total Oxidised Nitrogen (TON, NO_2 +NO_3-N) Ammoniacal Nitrogen (NH_3 + NH_4-N) Total Kjedahl Nitrogen (TKN) Total Nitrogen (TN)	Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short lived in the aquatic environment in the presence of oxygen and is typically an indication of a source of nitrogenous waste in the immediate vicinity of the sampling site. Ammonium-N and nitrate-nitrite-N are dissolved forms of nitrogen that are immediately available for plant and algae uptake and growth. Ammoniacal N is a combination of un-ionised ammonia (NH_3) and the ammonium ion (NH_4). Un-ionised ammonia is the more toxic form to aquatic life and is highly dependent on water temperature, salinity and pH. Total Kjedahl Nitrogen is the sum of ammoniacal nitrogen and organic nitrogen (amino acids and proteins). Total Nitrogen includes all forms of dissolved and particulate nitrogen (TKN + TON). Particulate nitrogen consists of plants and animals, and their remains, as well as ammonia adsorbed onto mineral particles. Particulate nitrogen can be found in suspension or in the sediment. Total Nitrogen is usually higher in upper estuarine sites where particulate matter is higher. Low dissolved forms of nitrogen compared to total nitrogen suggest that most of the nitrogen present is particulate matter such as plants, animals, and adsorbed to sediment particles. High nutrient levels can cause algal blooms, nuisance plant growth and eutrophication. High concentrations of some nutrients are also toxic to aquatic organisms.
Dissolved Reactive Phosphorus (DRP) Total Phosphorus (TP)	Phosphorus is found in water as dissolved and particulate forms. Dissolved Reactive Phosphorus is immediately available for uptake and growth by phytoplankton and macroalgae. Particulate phosphorus consists of plants and animals and their remains, as well as phosphorus in minerals and adsorbed onto mineral surfaces. Total Phosphorus is a measure of both dissolved and particulate forms in a water sample. The adsorption and desorption of phosphate from mineral surfaces forms a buffering mechanism that regulates dissolved phosphate concentrations in rivers and estuaries. Sources of phosphorus include sewage and animal effluent, cleaning products, fertilisers, and industrial discharges. Earthworks and forestry can also release phosphorus through soil erosion. Wetland drainage can expose buried phosphorus.

Appendix C. Attribute bands

Table C-1: 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

Table C-2: 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 C-3: Proposed Regional Attribute Bands for dissolved metal contaminants.

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

Appendix D. NPS-FM 2020 and regional attributes current state band by metric

Table D-1: Auckland region current state bands (2016-2020) broken down per metric by attribute.

Note the lowest band represents the overall band for each attribute. Bands in red denote bottom line failure. * = Interim grade (2018-2020 only), I.D = Insufficient data to calculate grade. N.A = not assessed.

Land cover	Site name	Copper		Zinc		*E. coli*				Nitrate (TON)		NH_4-N		DRP		Clarity (Turbidity)
		Med	95th	Med	95th	Med	95th	>260	>540	Med	95th	Med	Max	Med	95th	Med
Urban	Botany Creek	C	C	C	D	E	DE	E	E	A	B	A	D	B	C	B
	Pakuranga Creek	C	C	C	D	E	DE	E	E	A	A	C	C	D	D	B
	Oakley Creek	C	C	C	C	E	DE	E	E	B	B	A	A	D	C	A
	Omaru Creek	C	C	D	D	E	DE	E	E	A	B	A	C	D	C	A
	Ōtara Creek (South)	B	C	C	C	E	DE	E	E	A	B	A	C	C	B	A
	Oteha River	C	C	C	D	E	DE	E	E	A	A	A	C	C	B	C
	Avondale Stream	C	C	C	C	E	DE	E	E	A	A	A	A	B	B	C
	Lucas Creek	C	C	B	A	E	DE	E	E	A	A	A	A	B	A	B
	Puhinui Stream	B	C	C	D	D	DE	D	E	A	A	A	B	C	B	A
	Ōtara Creek (East)	B	C	B	C	E	DE	E	E	A	A	A	B	C	B	B
	Vaughan Stream	A	C	A	A	E	DE	E	E	A	A	A	A	B	B	C
Rural	Waitangi Stream	A*	A*	A*	A*	E	DE	E	D	C	C	A	A	B	A	A
	Whangamaire Stream	A*	A*	A*	A*	E	DE	E	E	D	D	A	B	B	A	B
	Ngakoroa Stream	A*	A*	A*	A*	D	B	D	B	C	C	A	A	A	A	A
	Kumeu River	B	C	B	A	E	DE	E	D	A	A	A	A	B	B	C
	Kaukapakapa River	B*	B*	I.D.	I.D.	E	DE	E	D	A	A	A	A	D	C	B
	Papakura Stream (Lower)	B	C	B	B	E	DE	E	E	A	A	A	B	D	D	A

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

Appendix E. Water Quality Index

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 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. This has been presented as an overview of water quality across Tāmaki Makaurau and differences between dominant land cover types (section 2.2). This enables us to compare overall river water quality across multiple parameters, in a relative sense, between sites.

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 ranging from Excellent, to Poor.

Water quality index methods

Each water quality index class and its associated narrative outcome is outlined in Table 7-1. 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) based on how many of the seven variables exceeded guidelines (scope), how often (frequency) and by how much (magnitude):

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

Table E-1: Water quality index class and scoring ranges used by Auckland Council.

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** the time.
80-94	Good	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels or water quality guidelines.
65-79	Fair	Water quality is usually protected, but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels or water quality guidelines.
45-64	Marginal	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels or water quality guidelines.
0-44	Poor	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels or water quality guidelines.

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 7-2). 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 2020 water quality index scores i.e. 2018 to 2020 (Foley, 2018; Buckthought et al., 2020).

Table E-2: River water quality index guideline values for the Auckland region (Buckthought et al., 2019).

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	

Water quality index results and discussion

The water quality index groups the exceedances for each site into three magnitudes: 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 sections 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 7.2.2 to 7.2.4. 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.

Regional

In the current assessment period of 2018-2020, nearly 60 per cent of monitored sites had water quality that was 'marginal' to 'poor' and 15 per cent of monitored sites had 'good' to 'excellent' water quality (Figure 7-1).

There was a smaller proportion of streams in the 'marginal' water quality class in 2018 to 2020 which appears to be primarily associated with scores fluctuating around the threshold between water quality classes (Figure 7-1). Refer to Table 7-3 for a summary of scores over the past rolling time period[13].

The most common water quality issues affecting monitored sites across the region were elevated total oxidised nitrogen, water temperature, and either lower or higher dissolved oxygen saturation (Figure 7-2). Over the previous four rolling time periods there were more guideline exceedances for temperature, total oxidised nitrogen, and turbidity, however all of these parameters had fewer exceedances in the latest rolling period. There was a higher proportion of exceedances of dissolved oxygen guidelines in the most recent rolling time period particularly in rural streams.

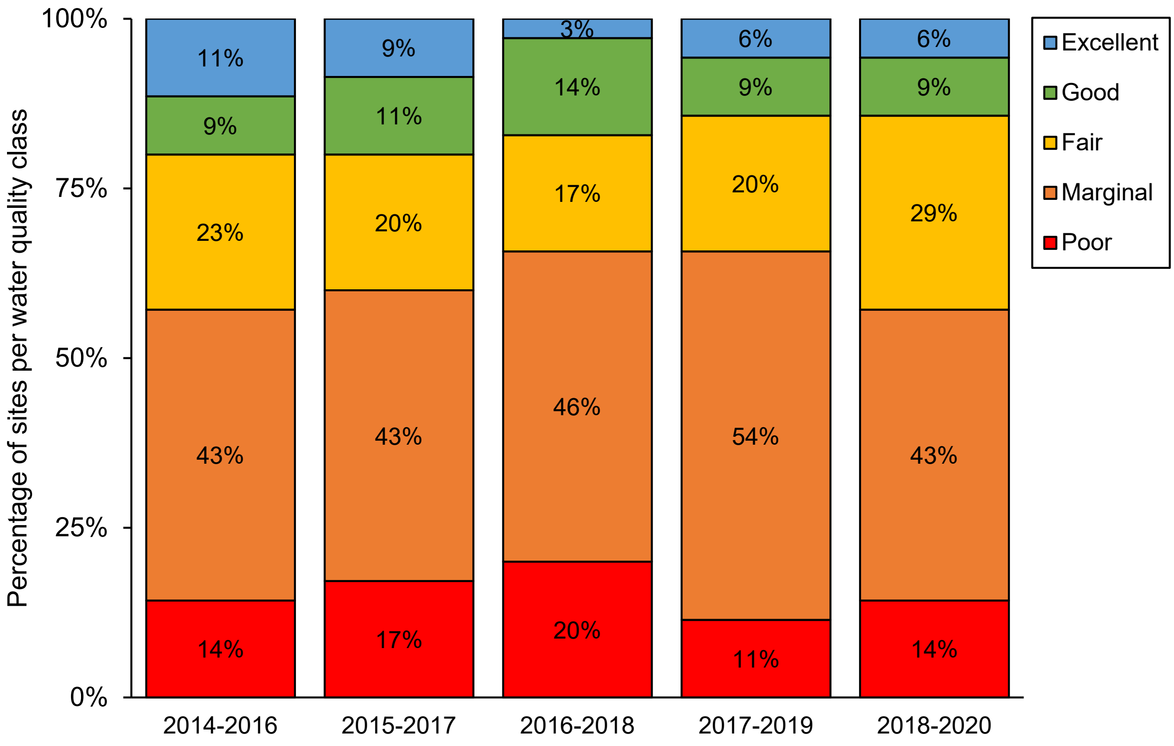


Figure E-1: Percentage of monitored sites (n=35) in each water quality index class for each three-year rolling period.

[13] Note that the summary across previous rolling time periods presented in Figure 3-11 and Figure 3-12 have been updated to exclude Otaki Creek for consistency.

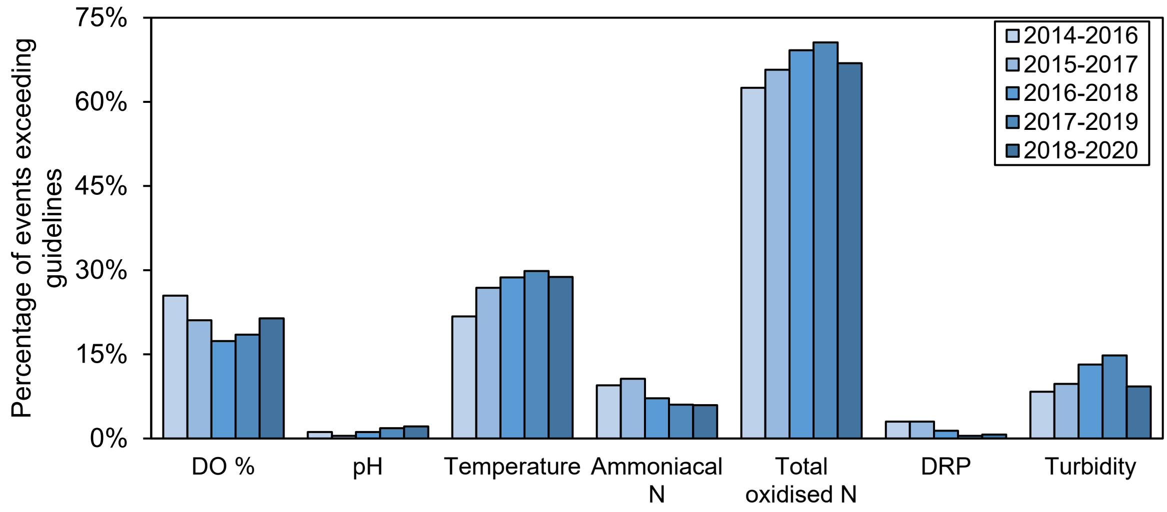


Figure E-2: Percentage of sampling events that exceeded the relevant water quality guideline for each three-year rolling period (n=35 sites).

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 (Figure 7-3). Rivers in urban catchments tend to be affected by elevated nutrients, 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. Each dominant land cover group is discussed further below, including patterns in individual parameters.

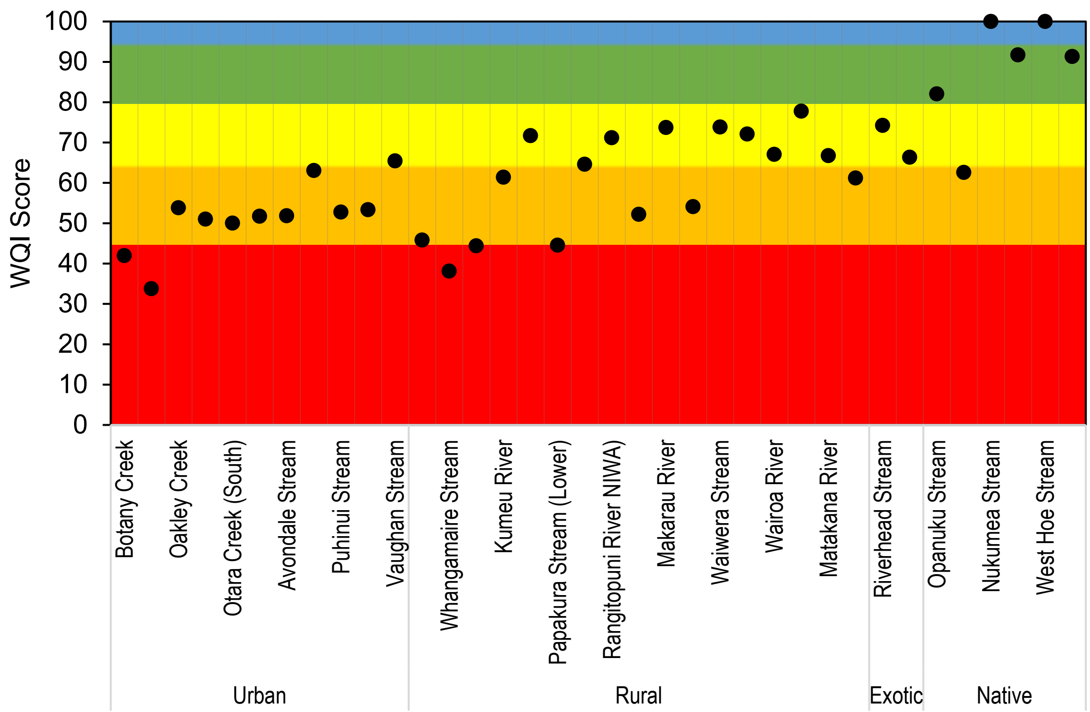


Figure E-3: Water quality index score for 2018-2020 (median values). Sites are ordered by highest percentage of urban or rural dominant land cover. Coloured bands indicate excellent (blue) through to poor (red) water quality index classes.

Native forest

As expected, water quality was typically within guideline values at the reference site streams (Figure 7-4). Guidelines were not exceeded for any of the seven parameters at Nukumea Stream and West Hoe Stream, which were consequently classed as 'excellent'. Wairoa Tributary was the only reference site with occasionally elevated total oxidised nitrogen levels. Surface water temperatures were also elevated in the well shaded Cascades Stream in the Waitakere Ranges.

Onetangi Stream and Opanuku Stream have more than 10 per cent of urban or rural land cover respectively within the upstream catchments and have higher concentrations of total oxidised nitrogen, and warmer water temperatures. Onetangi Stream was also more turbid and had lower dissolved oxygen levels throughout summer.

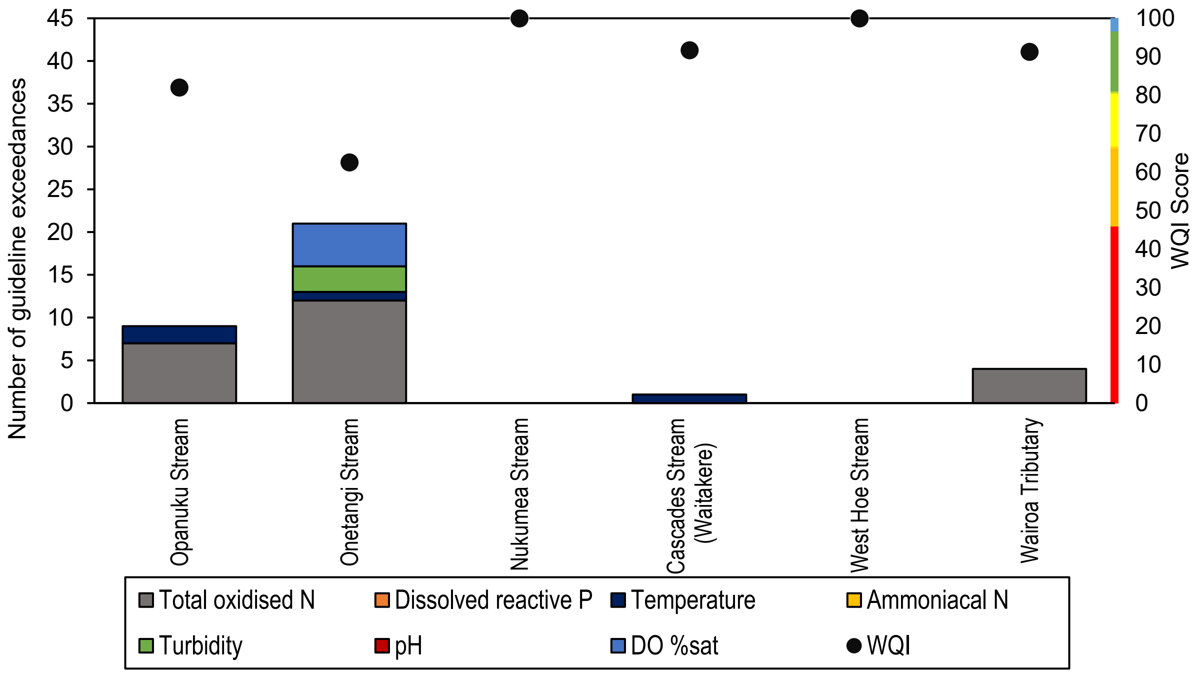


Figure E-4: Water quality index scores and number of exceedances of the relevant guideline value per site (2018-2020 median values) for native forest sites. Sites are ordered from lowest to highest percentage of native forest cover in the catchment.

Rural and exotic forest

Water quality was 'fair' to 'marginal' across sites dominated by rural and exotic forest land cover. Elevated total oxidised nitrogen, temperature, and turbidity, and low dissolved oxygen were the most common issues affecting these rural streams (Figure 7-5a.).

Three sites were classed as 'poor', Whangamaire Stream, Ngakoroa Stream, and Papakura Stream (Lower)), with a fourth site near the score boundary (Waitangi Stream). Poor water quality in three of these streams (Whangamaire Stream, Ngakoroa Stream, and Waitangi Stream) was driven by high magnitude exceedances of the total oxidised nitrogen guideline all of the time. Over the summer period, surface water temperatures were high and dissolved oxygen levels were low in these waterways. Poor water quality at Papakura Stream (upper) was driven by occasional exceedances of guidelines across five parameters as well as frequent exceedances of total oxidised nitrogen. Papakura Stream (upper) was the only rural stream with elevated dissolved reactive phosphorus, and one of only two rural streams that exceeded guidelines for ammoniacal nitrogen and had low dissolved oxygen levels more than 50 per cent of the time.

All other 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. Occasional high magnitude exceedances were also recorded at Wairoa River, and Mahurangi River (Forestry).

The temperature guideline was exceeded moderately frequently (less than 50 per cent of the time), at all sites except Cascades Stream (Waiheke), which is a well shaded site, and only occasionally at the exotic forestry sites. Dissolved oxygen guidelines were exceeded occasionally (typically seasonally or less than 25 per cent of the time), and more frequently at Rangitopuni River, Kaukapakapa River, and Riverhead Stream. 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.

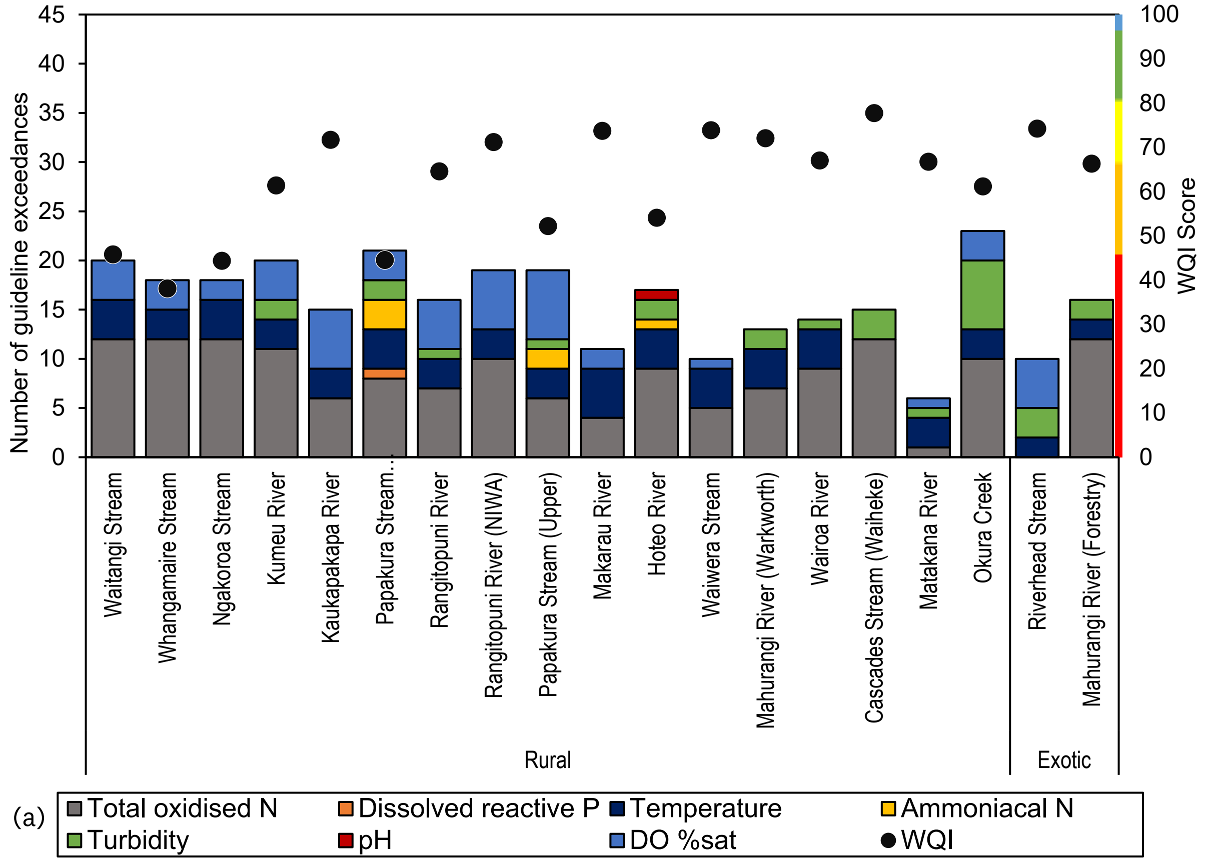
The turbidity guideline was exceeded at least occasionally at 12 out of the 19 sites, and at Okura Creek the guideline was exceeded 75 per cent of the time. Turbidity was elevated most commonly in winter and spring (June to September).

Urban

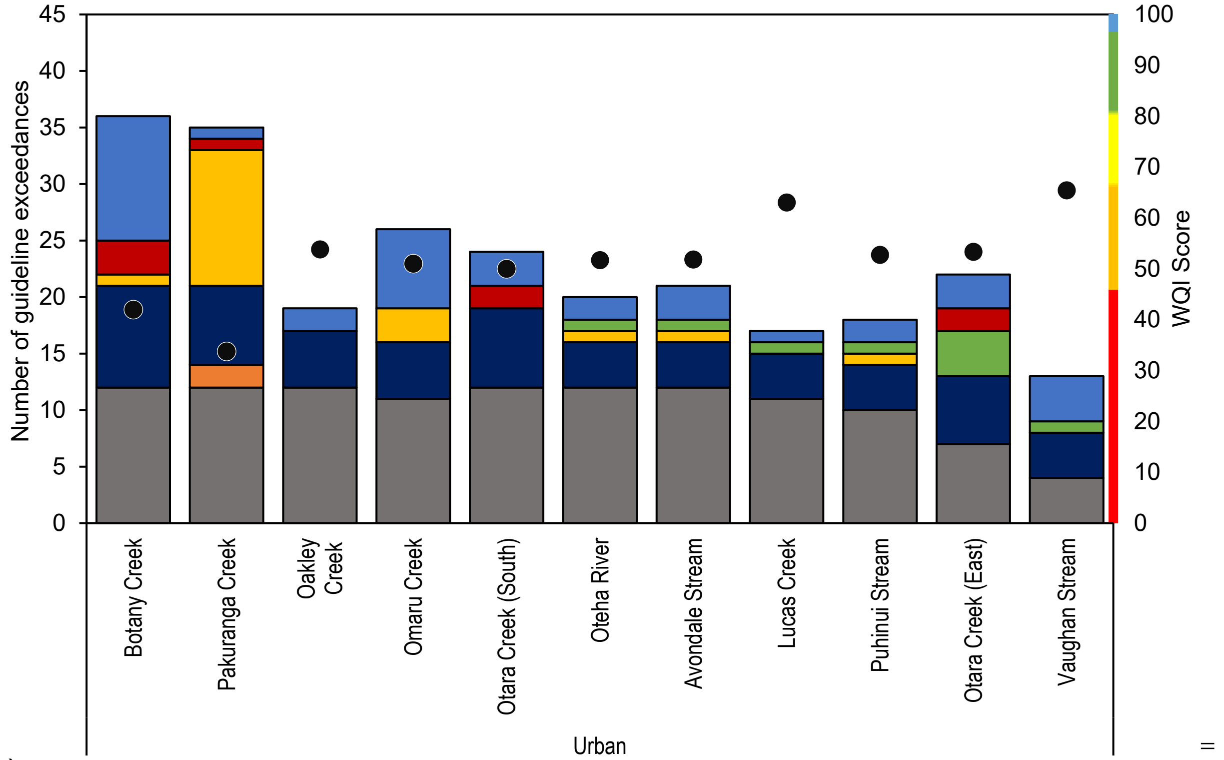
Water quality was ‘marginal’ at most sites dominated by urban land cover. Elevated total oxidised nitrogen, and temperature were the most common issues effecting these urban streams (Figure 7-5b). Urban sites tended to have fewer exceedances of the turbidity guideline than rural sites. Some urban streams also exceeded pH guidelines occasionally.

Two sites were classed as ‘poor’, Botany Creek and Pakuranga Creek. This was driven by a high frequency of guideline exceedances across several water quality parameters. Botany Creek had elevated temperatures, and consistently elevated dissolved oxygen levels above guidelines, for most of the time. 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. Botany Creek also had more alkaline water. Pakuranga Creek was the only stream that had consistently elevated ammoniacal N concentrations, and was the only urban stream that occasionally exceeded the dissolved reactive phosphorus guideline.

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, Ōtara Creek (South), and Omaru Creek.



(a)



(b)

Figure E-5: Water quality index scores and number of exceedances of the relevant guideline value per site (2018-2020 median values) for (a) rural and exotic forest and (b) urban sites. Sites are ordered by highest percentage of urban or rural dominant land cover.

Table E-3: River water quality index scores and classes based on rolling three-year median value across 2014 to 2020. Blue = Excellent, Green = Good, Yellow = Fair, Orange = Marginal, Red = Poor.
Sites are ordered by highest percentage of urban or rural dominant land cover.

Land cover	Site name	WQI Score (2014-2016)	WQI Score (2015-2017)	WQI Score (2016-2018)	WQI Score (2017-2019)	WQI Score (2018-2020)
Urban	Botany Creek	35.9	34.6	40.9	34.8	42
	Pakuranga Creek	32.4	39.2	33.3	33.1	33.8
	Oakley Creek	55.8	56.2	53	57.1	53.8
	Omaru Creek	40.5	43.4	46.1	45.3	51
	Ōtara Creek (South)	50.4	50.4	42.4	48.8	50
	Oteha River	52	52.4	53	58.5	51.7
	Avondale Stream	50.8	58.4	52.1	51.8	51.9
	Lucas Creek	62.1	61.8	61.4	61.4	63
	Puhinui Stream	65	57.5	49.6	64.2	52.8
	Ōtara Creek (East)	62.2	62.7	55.2	54.4	53.3
	Vaughan Stream	56.2	55.6	64.3	64.5	65.4
Rural	Waitangi Stream	48.1	46.1	44.8	45.1	45.8
	Whangamaire Stream	34.6	38.4	34.5	38.4	38.1
	Ngakoroa Stream	43.9	46.8	47	47.4	44.4
	Kumeu River	59.7	51.5	58.7	59.4	61.4
	Kaukapakapa River	47.5	46.8	62.7	63	71.7
	Papakura Stream (Lower)	51.3	42.9	42.8	44.1	44.5
	Rangitopuni River	66.4	63.3	64.3	63.2	64.6
	Papakura Stream (Upper)	49.5	40.9	41.1	49	52.2
	Makarau River	73.9	81.6	81.6	65.4	73.7
	Hoteo River (NIWA)	70.5	70.3	60.9	60.5	54.1
	Waiwera Stream	65.4	73	73.5	73.6	73.9
	Mahurangi River (Warkworth)	73.5	73.4	72.7	72.7	72.1
	Wairoa River	67.2	64.6	63.6	64.2	67
	Cascades Stream (Waiheke)	81.2	79.4	70.4	77.2	77.7
	Matakana River	83.1	83.1	75	74.9	66.7
	Okura Creek	45.9	61.6	62.3	61.2	61.2
	Riverhead Stream	65.8	66	66.1	74.2	74.2
Exotic	Mahurangi River (Forestry)	80.8	72.5	70.9	69	66.3
	Opanuku Stream	74.3	82.1	80.9	81.1	82.1
Native	Onetangi Stream	71.8	72.4	63.4	63	62.6
	Nukumea Stream	100	100	91.7	100	100.0
	Cascades Stream (Waitakere)	100	100	100	91.7	91.7
	West Hoe Stream	100	100	91.7	100	100.0
	Wairoa Tributary	100	91.7	91.7	82.6	91.3

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