Focus Catchments Programme Monitoring Report

Uretara Catchment and Ngongotahā Catchment

Prepared for Bay of Plenty Regional Council
Prepared by Beca Limited

6 March 2023

Revision History

Revision Nº	Prepared By	Description	Date
0	Genevieve Smith & Emily Fensham	Monitoring Report	1 November 2022
1	Genevieve Smith & Emily Fensham	Draft for release to client for review	9 December 2022
2	Genevieve Smith & Emily Fensham	Monitoring report for release	16 January 2023
3	Genevieve Smith	Client review and revisions	25 January 2023
4	Genevieve Smith	BOPRC Principal Scientist review and revisions	06 March 2023

Document Acceptance

Action	Name	Signed	Date
Prepared by	Genevieve Smith Emily Fensham		16 January 2023 16 January 2023
Reviewed by	Raymond Chang		16 January 2023
Approved by	Garrett Hall		16 January 2023
BOPRC Approval	James Dare		13 March 2023
on behalf of	Beca Limited		

Glossary

Abbreviation / Term	Description
A440	Colour Absorbance Coefficient at 440nm is a measure of yellow substance in the water.
Ammoniacal-N	Ammoniacal-nitrogen contains ammonia (NH_3) and ammonium (NH_4).
ANZECC	Australian and New Zealand Environment and Conservation Council. Author of the Australian and New Zealand Guidelines (ANZG) for Fresh & Marine Water Quality (2018) with ARMCANZ.
ANZG	Australian and New Zealand Guidelines for Fresh & Marine Water Quality, produced by ANZECC & ARMCANZ (2018).
Aquatic macrophytes	Aquatic macrophytes are major plants in waterways, such as aquatic ferns, mosses, water lily and weeds.
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand. Author of the Australian and New Zealand Guidelines for Fresh & Marine Water Quality (ANZG) (2018) with ANZECC.
Conductivity	Conductivity is an indirect measure of charged particles in water. Conductivity is commonly used to indicate the total dissolved solids in groundwater. The more dissolved salts in the water the higher the conductivity.
DGV	Default Guideline Values for physical and chemical stressors are values used to compare the state of water quality attributes to the expected values in reference ecosystems. Reference conditions are defined as the chemical and physical conditions that can be expected in rivers and streams with minimal or no anthropogenic influence.
DO	Dissolved Oxygen is the measure of the concentration of oxygen dissolved in the water. Aquatic life depend on oxygen to breathe, but this nutrient decreases with the growth of other nutrients and algae in the waterway.
DRP	Dissolved Reactive Phosphorus is a measure of the dissolved phosphorus compounds that are readily available for use by plants and algae.
E. coli	Escherichia coli is bacteria commonly found in the guts and faeces of warm-blooded mammals (including people) and birds. People can get sick if they drink, gather shellfish from, or swim in water that has high levels of *E. coli*. Common sources of *E. coli* bacteria are animal waste from farm stock and water fowl, storm water run-off and sewerage leaks.
FST	Faecal source tracking – laboratory assessment to identify the likely faecal source of *E. coli* contamination in water.
MWQG	New Zealand Microbial Water Quality Guidelines.
N	Nitrogen is an essential nutrient for plant growth that occurs naturally in rivers. High concentrations of Nitrogen stimulates excessive algae growth, which deteriorate river habitats and can be toxic to aquatic life.
NERMN	The Bay of Plenty Regional Councils' Natural Environment Regional Monitoring Network. Fulfils the statutory requirement of local government under the Resource Management Act (1991) to monitor and report on the State of the Environment, and to provide scientifically defensible information on the physical, chemical and biological characteristics of the natural resources of the Bay of Plenty region to assist in the preparation of BOPRC policies and plans, and monitoring of the effectiveness of such plans and policies.

Abbreviation / Term	Description
NNN	Nitrate Nitrite Nitrogen is a combination of nitrate nitrogen (NO_3^-) and nitrite nitrogen (NO_2^-). Periphyton is the slime and algae found on the bed of streams and rivers. They are a fundamental part of river ecosystems and are highly responsive to degradation of water quality.
pH	pH indicates the level of acidity and alkalinity on a logarithmic scale of 0 to 14, with low numbers being acidic and high numbers basic. Extreme pH causes harm to fish and invertebrates.
REC	River Environment Classification. The REC was developed by NIWA for MfE to provide a spatial framework for regional scale environmental monitoring and reporting, environmental assessment and management.
TN	Total Nitrogen is the sum of all organic and inorganic forms of nitrogen that are found in a water sample (i.e., nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), Ammoniacal-nitrogen (NH_4-N) and organic nitrogen such as amino acids or plant tissue. High Total Nitrogen can be a cause of eutrophication in lakes, estuaries and coastal waters and can cause algal blooms.
TP	Total Phosphorus is a measure of all forms of Phosphorus that are found in a sample, including dissolved and particulate, organic and inorganic. High levels of Total Phosphorus in water can come from either wastewater or run-off from agricultural land. Too much Phosphorus can encourage the growth of nuisance plants such as algal blooms.
TSS	Total Suspended Solids are particles of silt, clay, or organic matter suspended in a water. They affect invertebrate food quality and cause sedimentation of streams and estuaries. Hill country or stream bank erosion is a key contributor, often caused by stock traffic that loosen the soil in those sensitive areas. Soil type in a catchment affects the amount of suspended sediment. The faster a stream flows, the more suspended solids it can transport. When fine particles settle in slower-moving downstream areas, the spaces between rocks and gravel are filled making the bottom habitat unsuitable for fish and other aquatic species. Suspended solids can also impact on ecosystem health by reducing light penetration or clogging gills.

Executive Summary

The Focus Catchments Programme was developed in response to the Bay of Plenty (BOPRC) new key performance indicators (KPI) to improve swimmability in the Long-Term Plan 2018-2028. It also will inform alignment of land management work programmes with the emerging Essential Freshwater policy framework for the Ministry for the Environment. Previous reporting assessed water quality in 10 other Focus Catchments, but the Ngongotahā catchment and Uretara catchment were excluded, as their own monitoring programmes were in progress. This monitoring report presents the findings of data analysis from the Ngongotahā and Uretara catchments, and provides recommendations for future monitoring or land management actions.

Ngongotahā Catchment

Introduction & Methodology

- The primary environmental issue identified in the catchment was elevated *E. coli* bacteria.
- Water quality monitoring occurred over 2019 and 2020. Grab samples were collected from ten monitoring sites in the catchment and were analysed for physical parameters, chemical parameters, and *E. coli* concentration.
- Continuous flow data was collected in one location, and was used to create synthetic flow equations to calculate flow at the other sites.

Results

The following is a summary of key results:

- In general, the median *E. coli* concentrations at each monitoring station in the catchment are within the acceptable range for swimmability (<260 cfu/100 mL). One site (Ohinenui at 267 South Road) had a median *E. coli* concentration in the 'Alert/Amber' range (260-550 cfu/100 mL), and also had the greatest maximum concentration overall.
- The 95th percentile for nine of the ten monitoring sites are higher than the 'Red/Action' (>550 cfu/100 mL) threshold in the data collected over 2019 and 2020.
- The site at 'Ohinenui at 267 South Road' was one of the most upstream monitoring sites. This indicates that the land uses occurring in the west side of the catchment is affecting *E. coli* content prior to streams entering lowland areas / the Ngongotahā township.
- Ruminants were identified as the primary source of faecal contamination in samples that contained > 550 cfu/100 mL.
- When comparing 'summer' versus 'winter' sampling, there are a greater percentage of sample events that fall within the 'Alert/Amber' and 'Red/Action' ranges in summer than there are in winter. This is of significance, as a greater percentage of Amber and Red events are occurring during the season when people are likely to swim. There are two factors to consider. The first is that winter conditions are more likely to dilute nutrient and faecal inputs. The second is that the summer period is more likely to represent 'baseflow' conditions, which is the streamflow that is sustained between precipitation events and is fed by alternate / delayed pathways.
- It appears that, while other branches of the Ngongotahā catchment network do contribute to total *E. coli* load, they do not appear to be the primary / initial sources of *E. coli* to the Ngongotahā Stream. The loads within the Ngongotahā Stream itself are an order of magnitude greater than the values from the other tributaries.

Recommendations

The Ngongotahā Stream conveys greater *E. coli* loads compared to the other streams and tributaries that join with it. Additionally, there is an unusually high load conveyed from Paradise Valley that requires investigation.

i. **Continue monitoring to assess whether the piggery closure has had an effect on catchment water quality.**

   A pig farm that was allowing effluent to directly enter the Ngongotaha network was closed in January 2022, which may affect the recommendations of the present results. The effects of closing the piggery on water quality has not been quantified, as monitoring concluded prior to its closure.

ii. **Establish monitoring sites on the western perimeter of the Ngongotahā catchment to provide greater resolution of potential *E. coli* sources**

   The monitoring data indicates that the source of *E. coli* loading is in the upper reaches of the Ngongotahā catchment, affecting the Ngongotahā Stream and Ohinenui Stream prior to monitoring sites. It is recommended that monitoring occurs in the upper reaches of the Ohinenui Stream and Ngongotahā Stream. In doing so, the effects of the upslope agricultural activities may be isolated and identified.

iii. **Provide education and services to encourage the protection of waterways (e.g. fencing, stock exclusion, bridges), and continue monitoring to assess whether introducing these measures / inhibiting direct deposition into waterways reduces *E. coli* loads during the summer period.**

   Currently, there is a greater percentage of sample events in the allocated summer period that exceed Amber or Red *E. coli* thresholds, and there are very few sample events in the winter period that exceed these thresholds. This may be due to the effects of dilution in winter or may indicate that direct deposition of faecal matter is occurring within waterways. By encouraging stock exclusion from waterways, future *E. coli* monitoring can be used to assess whether direct deposition was a primary contributor, or whether diffuse sources are still contributing significant *E. coli* loads during summer.

iv. **Assess the activities at / upstream of the Paradise Valley wildlife park**

   The Ngongotahā Stream monitoring site at Paradise Valley is located downstream of a wildlife park with grazing animals and a waterfowl wetland. Viewing/assessing the site and its activities may be beneficial to identify potential sources of faecal contamination in the waterway (e.g. waterfowl nesting areas, the sheep facilities).

v. **Establish a monitoring site upstream of the Paradise Valley wildlife park**

   If the site walkover of the park and activities is inconclusive, it may be necessary to establish the monitoring site for *E. coli* concentration and FST upstream of the wildlife park, to eliminate the potential effects of the park on results.

vi. **Explore the costs and benefits of a more bespoke public health risk model for the Ngongotaha catchment and wider Rotorua area.**

   With the existing *E. coli* database, it may be beneficial to investigate a bespoke Quantitative Microbial Risk Assessment (QMRA) for the relative health risk posed by *E. coli* exposure at swimming sites. Currently, a generalised public health system assessment is utilised in the Rotorua region to assess swimmability and safety. However, it may be beneficial to use the data collected establish a relative target for the swimming sites that, on balance, is achievable and low risk to the public.

Beyond the characterisation of the Ngongotahā catchment, the following assessments may be beneficial in the future, but are not pertinent to present characterisation and mitigation of waterways in the Ngongotahā catchment.

- Investigate potential *E. coli* contributions in groundwater and/or interflow from adjacent upslope catchments into the Ngongotahā catchment. The well-drained, productive land upslope / outside of the Ngongotaha catchment may be a source of contamination in the headwaters of the Ohinenui and Ngongotaha streams via overland flow, near-surface transport, or groundwater flow. An assessment of the subsurface gradient may provide information on the source of contamination within the catchment.
- Investigate the potential extent of *E. coli* transmission via porous volcanic soils.

Uretara Catchment

Introduction & Methodology

- The environmental issue identified in the Uretara catchment is elevated *E. coli* levels in water.
- Water quality monitoring occurred regularly in 2018, and quarterly in 2020 to 2022. Grab samples were collected from 14 monitoring sites in the catchment and were analysed for physical parameters, chemical parameters, and *E. coli* concentration.
- Continuous flow data was collected in one location and was used to create synthetic flow equations to calculate flow at the other 13 sites.

Results

The following is a summary of key results:

- Water quality monitoring indicates that land uses in the upland catchment are affecting *E. coli* content prior to streams entering lowland areas.
- In general, the *E. coli* load increases from upstream to downstream, but the concentration does not reflect this increase. This indicates a dilution effect in the Uretara stream.
- Based on the data collected between 2018 and 2022, the swimming site (Henry Road Ford) falls into attribute band D (orange) in the National Policy Statement for Freshwater Management framework, which indicates a predicted average *Campylobacter* infection risk greater than 3%.
- The median *E. coli* concentrations across the Boyd Tributary and Quarry Creek networks are generally within the 'Alert/Amber' range for swimmability. The median *E. coli* concentrations for the Uretara stream monitoring sites were primarily in the 'Green/Acceptable' range, apart from the most downstream site (Henry Road Ford).
- Faecal sources were ruminant, with some avian sources noted.
- When comparing 'summer' versus 'winter' sampling, there are a greater percentage of sample events that fall within the 'Alert/Amber' and 'Red/Action' ranges in summer than there are in winter. This is of significance, as a greater percentage of Amber and Red events are occurring during the season when people are likely to swim. There are two factors to consider. The first is that winter conditions are more likely to dilute nutrient and faecal inputs. The second is that the summer period is more likely to represent 'baseflow' conditions, which is the streamflow that is sustained between precipitation events and is fed by alternate / delayed pathways.

Recommendations

Overall, the catchment would benefit from ongoing monitoring and engagement to improve water quality.

i. **Create and refine synthetic flow equations for the other sites in the catchment, to allow for load calculations across the catchment. Alternatively, consider other approaches to estimating flow rates within the catchment.**

Refining flow measurement would mainly be of benefit to determine relative loads once the primary source of *E. coli* is established. A potential method would be to estimate the ratio of smaller streams to gauged sites, and crudely calibrate a flow model for the catchment. Alternatively, a proportional approach could be used, in line with the work done in the Ngongotahā catchment.

However, this is not considered a key action at this stage of data collection.

ii. Investigate *E. coli* sources within the indigenous forest upstream of the Boyd Tributary, Peach's Creek and Quarry Creek, and potential avian sources in the lowland areas.

Carry out a site walkover of the upper reaches of the creeks and tributary, to assess whether there are any established colonies or evidence of wildlife that are contributing to *E. coli* loads in the indigenous forest. The wetland upstream of Peach's Creek monitoring site should be investigated.

There are indications of an avian faecal source, particularly in the lower monitoring area at Henry Road Ford. Additional lowland surveys may be beneficial. However, previous initiatives (i.e. goose colony culling and manure management) does not appear to have a conclusive influence.

iii. Further investigation into *E. coli* sources in the Uretara catchment.

It may be prudent to conduct a specific programme for FST data in the Uretara catchment. Based on the FST data presented, many samples do not provide any conclusive source of faecal contamination or can only account for a small percentage of the source. Having a stronger understanding of the source may improve the ability to create a targeted mitigation strategy. One method would be to filter a larger volume of water to increase the amount of sample to analyse.

iv. Specifically, investigate *E. coli* sources in the farmland upstream of the Peach's Creek, Boyd Tributary, Boyd Creek and Quarry Creek sites, and support Land Management Officers to engage with the community/land managers to explore water quality measures.

As ruminant sources have been identified, mitigation measures in the farmland between the forest and the first monitoring sites should be investigated and encouraged. These include:

- Riparian planting,
- Creating exclusion zones, fencing, and reducing the number of stock crossings in streams,
- Introducing and encouraging best practice around farm dairy effluent management and discharge to waterways

Additionally, current *E. coli* results show that *E. coli* concentrations in the summer periods are greater than in the winter periods. This is either due to the effects of dilution, or may suggest that direct deposition of faecal matter into waterways is occurring. By encouraging and instigating stock exclusion measures, further monitoring may be able to identify whether this was a primary source of *E. coli* loads during the summer months.

v. Investigate mitigation measures between the Quarry on Wharawhara Road and Peach's Creek/Quarry Creek

The median sediment load into Peach's Creek and Quarry Creek is the greatest in the catchment. They are adjacent to an active quarry, and may be negatively affected by the soil disturbance activities occurring. An investigation should be carried out to identify potential sediment loss pathways, and sediment mitigation measures should be explored between the Quarry and creeks.

1 Introduction

1.1 Focus Catchments Programme

The Focus Catchments Programme was developed in response to Bay of Plenty Regional Council's (BOPRC) new key performance indicators (KPI) to improve swimmability in the Long-Term Plan 2018-28, and to inform alignment of land management work programmes with the emerging Essential Freshwater policy framework from the Ministry for the Environment. The programme aims to provide a more refined approach to guide the Integrated Catchment Management group's work on water quality in key areas and help prioritise Council's grant funding incentives to community. A total of 12 Focus Catchments[1] were selected for the start of the programme, based primarily on known water quality monitoring data and key issues in these catchments.

Previous reporting (Mahon et al, 2020; Zygadlo et al, 2022) has assessed the water quality information for 10 of the 12 Focus Catchments. These reports collated the historical and current water quality information and provided water quality monitoring recommendations for those catchments. Two Focus Catchments (Uretara and Ngongotahā) were not included in these reports, as they had more specific monitoring programmes underway. The data from these monitoring programmes are now the subject of this report, and the following information may be used to inform management for specific reductions in contaminant levels. The work is intended to compliment the Councils regulatory functions and does not reduce the level of service that the land management team provides to care groups, Coast Care, or biodiversity sites outside of Focus Catchments.

1.2 Purpose of this report (Take)

The present report will:

- Collate, analyse and present the findings of data from the two Focus Catchments that were previously excluded from reporting (Uretara and Ngongotahā).
- Provide recommendations for future monitoring, and suggestions for prioritised land management actions.

1.3 Structure of this report (Te Hanganga o te Pūrongo)

The structure of this report is largely similar to that used by Mahon et al. (2020) and Zygadlo et al. (2022), as the target audience, use, and purpose remains the same.

An overview of methodologies used in the field and laboratory will be presented in Chapter 2, along with a summary of statistical analyses used. This will remain consistent throughout the report, unless otherwise stated. Chapters 3 and 4 will discuss the data, findings and recommendations of the Ngongotahā and Uretara catchments, respectively. They will largely be structured in the same way, including: a summary of the key points found during the analysis; a summary of known issues in the catchment; results reporting; a discussion of findings; and management implications within the Focus Catchment. Each chapter will conclude with recommendations for future proposed monitoring, if applicable, and any specific areas in the catchments that may benefit from further investigation or management.

Separate appendices are attached to Chapters 3 and 4, which detail statistics from individual monitoring sites within the catchment. This includes summary statistics of nutrients, E. *coli* and flow.

Chapter 5 summarises the finding and recommendations of the two Focus Catchments.

---

[1] Focus catchments (boprc.govt.nz)

2 Methodology

2.1 Water quality data collection (Te kohikohinga Raraunga Kounga Wai)

Sample collection was carried out by Bay of Plenty Regional Council's Coastal Catchments Land Management Team, summer students, and Laboratory and Data Services staff.

Physical attributes (e.g. water temperature, dissolved oxygen and conductivity) were recorded on hand-held water quality meters. Water samples were stored on ice while transported to the laboratory. Samples were processed for the parameters listed in Table 2-1, to meet the aims of the Focus Catchment monitoring programme.

The following should be noted about the method of sampling:

- These samples are spot samples taken at inconsistent times of day, which does not capture the diurnal variation in physical attributes such as temperature, pH and dissolved oxygen.
- Sampling was limited to a short time period does not represent the established seasonal variation seen in some catchments for some attributes (see the past monitoring summary sections where applicable).
- The sampling regime was systematic (i.e. occurring on a schedule), which does not account for specific events (e.g. rainfall, high flow).

Supplementary environmental/climate data was sourced where needed to complete data cleansing and catchment rainfall and/or flow analysis from the nearest NERMN site with rainfall and/or flow monitoring.

2.2 Lab analyses (Ngā Tātari Taiwhanga)

Analyses were performed by the Bay of Plenty Regional Council Laboratory. Table 2-1 details the methods used for chemical/biological analysis of water samples.

Table 2-1. Laboratory methods used for analyses of chemical and biological parameters in water samples.

Parameter	Method	Detection Limits/Units
Ammonium Nitrogen (NH_4-N)	APHA 4500-NH_3 H (modified) by Flow Injection Analyser	0.002 g/m^3
Nitrate-Nitrite-Nitrogen (NNN)	APHA 4500-NO_3-I (modified) by Flow Injection Analyser	0.001 g/m^3
Total Nitrogen (TN)	APHA 4500-P J (modified) by Flow Injection Analyser	0.01 g/m^3
Dissolved Reactive Phosphorus (DRP)	APHA 4500-P G by Flow Injection Analyser	0.001 g/m^3
Total Phosphorus (TP)	APHA 4500-P J (modified) by Flow Injection Analyser	0.001 g/m^3
Turbidity	APHA 2130 B (modified) by white light turbidity meter	0.1 NTU
pH	APHA method 4500-H+ measurement at 25°C	0.1
Conductivity	APHA method 2510B	1 µS/cm at 25°C
Total Suspended Solids (TSS)	APHA 2540 D dried at 103-105°C	1 g/m^3
Water Clarity (Transmissivity)	C-Star Transmissometer	0.18 m
Escherichia coli (E. coli)	APHA 9213D by membrane filtration (mTEC agar)	1 cfu/100 ml

2.3 Statistical analysis (Huarahi)

Water quality summary statistics and graphics were prepared using RStudio for all monitoring locations. For catchments with ≤ 10 samples in the dataset (post-data cleansing), individual points were plotted per attribute in graphs instead of boxplots, as there was insufficient data to calculate quartile statistics.

2.4 Comparisons to freshwater guidelines (Huarahi)

2.4.1 Australian & New Zealand Guidelines for Fresh and Marine Water Quality

A simple comparison was made between the calculated median for each attribute per site with accepted Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG) Default Guideline Values (DGVs) for physical and chemical stressors, in accordance with previous BOPRC monitoring assessments.

These guidelines were established based on reference sites throughout New Zealand in different River Environment Classifications (REC). Reference conditions in the guidelines were determined from locations that are minimally impacted and have low exposure to anthropogenic drivers. They are therefore an indication of what sites would have been like with minimal human impact. However, most sites monitored in the present study are highly modified environments and do not qualify as reference sites. The DGV were included for some context of impact.

Depending on the parameter/stressor, there are two different percentiles that are determined for the DGV:

- The 80th percentile for those physical and chemical stressors that are harmful at high values (e.g. nitrate, Ammoniacal-N, phosphorus, TSS); and
- The 20th percentile for those that are harmful at low values (e.g. dissolved oxygen, water clarity).

The selected percentile is specified in Tables 2-2 and 2-3.

The DVGs are not toxicity thresholds, rather, 80% (or 20%) of the reference sites in the ‘warm wet low elevation’ and ‘cool wet hill’ category fall below the recorded value in Table 2-2 and Table 2-3, respectively. Values higher (i.e. worse) than the indicated DGVs suggest an adverse effect or exposure to anthropogenic drivers, and that further investigation may be required. Note that, in regard to dissolved oxygen and water clarity, values lower than the indicated DGVs are considered ‘worse’.

Table 2-2. ANZG physical and chemical stressor Default Guideline Values for warm wet low elevation REC class (ANZECC & ARMCANZ, 2018).

Parameter	ANZG DGV Threshold	Value
Conductivity	80^{th} percentile	115 µS/cm
Dissolved oxygen	20^{th} percentile	92%
pH	20^{th} percentile	7.26
Total nitrogen	80^{th} percentile	0.292 g/m^3
Ammoniacal nitrogen	80^{th} percentile	0.01 g/m^3
Nitrate nitrite nitrogen	80^{th} percentile	0.065 g/m^3
Total phosphorus	80^{th} percentile	0.024 g/m^3
Dissolved reactive phosphorus	80^{th} percentile	0.014 g/m^3
Total suspended solids	80^{th} percentile	8.8 g/m^3
Turbidity	80^{th} percentile	5.2 NTU
Water clarity	20^{th} percentile	0.8 m

Table 2-3. ANZG physical and chemical stressor Default Guideline Values for cool wet hill REC class (ANZECC & ARMCANZ, 2018).

Parameter	ANZG DGV Threshold	Value
Conductivity	80^{th} percentile	95 µS/cm
Dissolved oxygen	20^{th} percentile	86%
pH	20^{th} percentile	7.35
Total nitrogen	80^{th} percentile	0.238 g/m^3
Ammoniacal nitrogen	80^{th} percentile	0.006 g/m^3
Nitrate nitrite nitrogen	80^{th} percentile	0.087 g/m^3
Total phosphorus	80^{th} percentile	0.016 g/m^3
Dissolved reactive phosphorus	80^{th} percentile	0.008 g/m^3
Total suspended solids	80^{th} percentile	2.6 g/m^3
Turbidity	80^{th} percentile	2.4 NTU
Water clarity	20^{th} percentile	1.6 m

Comparisons have also been made to the ANZG toxicant DGVs (toxicant DGVs) (see Table 2-4). These have largely been adopted from the Australia New Zealand Environment Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) (2018) guidelines with updates from more recent research. The ANZG toxicant DGVs provide different values for different levels of species protection (80%, 90%, 95%, and 99%) and generally account for protection against chronic toxicity. Advice on what level of protection should be applied is within the guidelines. In general, the default for slightly to moderately disturbed ecosystems is the 95% protection level. Ammoniacal-N concentrations in the ANZECC & ARMCANZ guidelines (2018) has been adjusted to the median pH in each catchment, based on the summary statistics for each catchment. These have been presented in appendices at the end of each catchment report.

Table 2-4. Toxicity DGVs for nitrate (Hickey, 2013) and ammonia (ANZECC & ARMCANZ, 2018).

Parameter	Toxicity Guideline	Value – Annual Median
Nitrate	95% species protection	2.4 g/m^3
Ammonia (Ngongotaha, pH 7.11)	95% species protection	2.2 g/m^3
Ammonia (Uretara, pH 7.03)	95% species protection	2.1 g/m^3

2.4.2 National Policy Statement for Freshwater Management

An alternative guideline is available in the National Policy Statement for Freshwater Management 2020 (NPSFM 2020) (MfE, 2020). The NPSFM provides median and 95^{th} percentile attribute states for physical and chemical parameters, in the context of ecosystem health and water quality. The median values are separated into attribute bands, from A (best) to D (worst). These attribute states will be referred to when discussing results. Please note, the present assessment was carried out prior to the release of the NPSFM amendment dated 8 December 2022. The December 2022 amendment included a change in the required national bottom lines for ammonia and nitrate toxicity attributes, where the values to protect 95% of species from toxic effects is now used rather than the 80% protection value. In general, this does not greatly affect the outcome of reporting.

pH results are compared to the pH Attribute bands in Table 2-5 (Carter et al. 2017). This provides a national reference framework for expected pH levels in rivers and streams in the Bay of Plenty. It is important to note that this framework was designed to apply throughout the diel (24-hour) regime of pH measurements and not just to the narrower range of daytime 'spot' measurements that have been used in the Focus Catchment investigations, however it provides context for what are considered "normal" pH levels.

Table 2-5. Attribute table for pH regimes in rivers and streams (Carter et al. 2017).

pH attribute band	Numeric attribute state	Narrative attribute state
A	>6.5 and <8.0	No stress caused by acidic or alkaline ambient conditions on any aquatic organisms that are present at matched reference (near-pristine) sites.
B	>6.5 and <8.5	Occasional minor stress caused by pH on particularly sensitive freshwater organisms (i.e. fish and insects).
C	>6.0 and <9.0	Stress caused on occasion by pH exceeding preference levels for certain sensitive insects and fish for periods of several hours each day.
D	<6.0 or >9.0	Significant, persistent stress caused by intolerable pH on a range of aquatic organisms. Likelihood of local extinctions of keystone species and destabilisation of river ecosystems.

2.4.3 *E. coli* Screening Criteria

The *E. coli* results were compared to the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MWQG) (MfE, 2003). This comparison provides an indication of what healthy recreational contact conditions are (see Table 2-6). The percentage of events within each bracket was collated for the swimming sites in each catchment and compared to the attribute bands for *E. coli* presented in the NPSFM. Based on this, the potential risk of *Campylobacter* infection was estimated.

Table 2-6. Threshold values and implications for health of the Microbiological Water Quality Guidelines for Freshwater Recreational Areas (MfE, 2003).

MWQG Threshold	Numerical Value	Implication
Acceptable	<260 cfu/100 mL	Safe for swimming
Alert	260-550 cfu/100 mL	Caution advised
Action	>550 cfu/100 mL	Unsafe for swimming

2.5 Faecal Source Tracking (Te Haurapa Tāhawahawa Tūtae)

Faecal source tracking (FST) is used to identify the source of faecal indicator bacteria. It is indicative of the faecal bacteria present in the watercourse at the time of sampling. It is best practice to gather multiple FST samples at a site to identify the main sources of faecal bacteria, and effort made to represent a range of flow conditions (e.g. baseflow, rainfall events). Samples are processed as per the methodology specified by the analysing laboratory, the Institute of Environmental Science and Research (ESR). Further details are available on ESR's website[2].

[2] https://www.esr.cri.nz/home/about-esr/ourscience-in-action/identify-the-source-of-faecal-contamination/

3 Ngongotahā, Rotorua

3.1 Introduction (Kupu Whakataki)

Existing summary statistics indicate that, when compared to overall monitoring data from across the Bay of Plenty region, the Ngongotahā stream at State Highway 36 (SH36) is in the worst 50% of sites for Total N, Total P, NNN, DRP, NH_4-N, TSS and water clarity. It is within the worst 25% of sites for *E. coli* concentrations.

The Ngongotahā stream has been identified as having elevated faecal contamination levels relative to other sites in the Bay of Plenty. The Railway Bridge bathing site in the Ngongotahā catchment is ranked as one of the highest risk bathing sites in the region. Results collated between 2012 and 2017 report a mean *E.coli* concentration of 481 cfu/100mL, which sits within the 'Alert/Amber' (260-550 cfu/100mL) threshold set in the Microbiological Water Quality Guidelines. Over this period, 18% of samples had concentrations in excess of the 'Action/Red' threshold (>550 cfu/100 mL).

According to a previous bathing report produced in 2020, Ngongotahā at Railway bridge went down a band for the human contact attribute for *E. coli* (NPS-FM, Table 9) to the 'E' ranking. The statistics at the site also indicated that contamination events have become larger (i.e. greater concentrations during sampling) and more frequent with time, often exceeding the 'Action/Red' threshold (Dare, 2020). Assessment of the 'Railway Bridge' bathing site against the swimmability attribute in Appendix 2 of the National Policy Statement suggests that 20-30% of the time, the estimated risk of Campylobacteriosis is greater than 5%, and that the predicted average infection risk is greater than 3%. Therefore, this site is currently deemed unsuitable for recreational contact, and it is necessary to identify the contaminant source(s).

3.2 Purpose (Take)

The objectives for this investigation were to determine where faecal contamination is coming from within the Ngongotahā catchment and when contamination levels are the highest to support next steps, future monitoring, and land management recommendations.

3.3 Catchment Description (Whakaaturanga o te Takiwā)

The Ngongotahā Stream is Lake Rotorua's largest tributary. It drains 70 km^2 of land on the west side of Lake Rotorua, covering the back of Mt Ngongotahā, Paradise Valley, and parts of the Mamaku plateau. The catchment geology is volcanic, characterised by soft unconsolidated to moderately consolidated deposits in areas of rhyolitic or andesitic ash base rock aligned with areas of more moderately undulating slopes.

The catchment is largely pastoral with significant areas of native bush and some forestry. According to catchment analysis completed in 2005 (Beyá, Hamilton & Burger, 2005), land use in the Ngongotahā catchment consists predominantly of pasture (48.5%) and indigenous forest (36.8%), as well as some forestry (11.4%), scrub land (2.5%) and urban/urban open space (0.86%).

The township of Ngongotahā lies at the bottom of the catchment on the shores of Lake Rotorua. Recreational use of the stream includes swimming during summer months and flyfishing which is popular year-round between the stream mouth to the State Highway 5 bridge.

3.4 Key Issues (Ngā Kaupapa Mātuatua)

The key water quality issue identified in the catchment is elevated levels of *E. coli* bacteria. These elevated levels have caused the lower area of the Ngongotahā Stream to consistently be unsafe for swimming. The stream flows to the shore of Parawai Bay, where recreational activities such as fishing, swimming and boating occur.

Ngongotahā at Railway Bridge is graded an 'E' for the *E. coli* attribute in the NPS-FM and is therefore deemed 'not suitable for primary contact'. Outflow from the Ngongotahā River, especially after large rainfall events, is likely to be causing elevated concentrations at the Ngongotahā bathing site in Lake Rotorua. This site is the worst performing lake bathing site and is currently graded a 'D' for the *E. coli* attribute.

3.5 Methodology (Huarahi) / Monitoring Summary

Ten sites were monitored in the Ngongotahā catchment from July 2019 to December 2020 (Table 3-1). Samples from each site were screened for *E. coli*, nutrients, sediment, and field parameters (e.g. pH, water clarity). Sampling occurred quarterly, at minimum. The monitoring sites were established to target various sub-branches that feed into the Ngongotahā Stream, in order to identify potential contaminant contributions. Images depicting the location of each monitoring site can be viewed in **Appendix A**.

For the purposes of spatial analysis from upstream to downstream in the catchment, the sites have been ordered as shown in Table 3-1. The rationale selected was to order by 'branches' of streams, and then from upstream to downstream in the Ngongotahā stream. Tributaries that feed into the Ngongotahā stream and are not connected to other sites are grouped as 'tributaries of Ngongotahā stream'. All graphs will be presented in this order. The monitoring site locations are shown in Figure 3-1.

Table 3-1. Identification and locations of water quality sites in the Ngongotahā catchment.

Site Name	Site ID	Latitude	Longitude
Umurua Network			
Ohinenui at 267 South Rd	DK178765	-38.1195	176.0999
Umurua at U/S Ngongotahā Confluence	DK703826	-38.101	176.1594
Tributaries of Ngongotahā Stream			
North Trib u/s Ngongotahā confluence	DK562743	-38.1088	176.1436
Relph Rd Trib u/s Ngongotahā confluence	DK627492	-38.1313	176.1519
Ngongotahā Stream			
Ngongotahā at Paradise Valley	DK618481	-38.1323	176.151
Ngongotahā at Paradise Valley Rd	DK574761	-38.1202	176.1455
Ngongotahā u/s Ngongotahā North Trib confluence	DK578729	-38.1101	176.1455
Ngongotahā at Above Umurua Confluence	DK700820	-38.1015	176.159
Ngongotahā at SH5	DK982984	-38.0859	176.1905
Ngongotahā at SH36	EL174017	-38.0824	176.2122

Table 3-2 provides basic descriptions of the land use and topography at each site. For the purposes of water quality assessment under the ANZG criteria, each site has been given a designation of either 'warm, wet, low' (i.e. WWL) river environmental classification (REC) or 'cool, wet hill' (i.e. CWL) REC.

Table 3-2. Landscape descriptions at the Ngongotahā monitoring sites (CWH = Cool wet hill REC, WWL = warm wet low REC)

Site Name	Land Type[3]	Land Cover[4]	ANZG REC Class
Umurua Network			
Ohinenui at 267 South Rd	Steep hills	Indigenous forest	CWH
Umurua at U/S Ngongotahā Confluence	Flat to gently undulating	High producing exotic grassland and some exotic forest	WWL
Tributaries of Ngongotahā Stream			
North Trib u/s Ngongotahā confluence	Steep hills	Broadleaved indigenous hardwoods	CWH
Relph Rd trib u/s Ngongotahā confluence	Steep hill country	High producing exotic grassland and some exotic forestc	CWH
Ngongotahā Stream			
Ngongotahā at Paradise Valley	Steep hill country	High producing exotic grassland and some exotic forest	CWH
Ngongotahā at Paradise Valley Rd	Rolling to strongly rolling slopes	High producing exotic grassland and some exotic forest	CWH
Ngongotahā u/s Ngongotahā North Trib confluence	Rolling to strongly rolling slopes	Broadleaved indigenous hardwoods	CWH
Ngongotahā at Above Umurua Confluence	Flat to gently undulating	High producing exotic grassland and some exotic forest	WWL
Ngongotahā at SH5	Flat to gently undulating	High producing exotic grassland and some exotic forest	WWL
Ngongotahā at SH36	Urban area	High producing exotic grassland and urban areas	WWL

[3] NZLRI Land Use Capability 2021 – LRIS Portal, 2021. Retrieved from https://lris.scinfo.org.nz/search/?q=land+use. Accessed on 8 November 2022.

[4] LCDB v5.0 – Land Cover Database version 5.0, Mainland, New Zealand – LRIS Portal, 2020. Retrieved from https://lris.scinfo.org.nz/search/?q=land+use. Accessed on 8 November 2022.

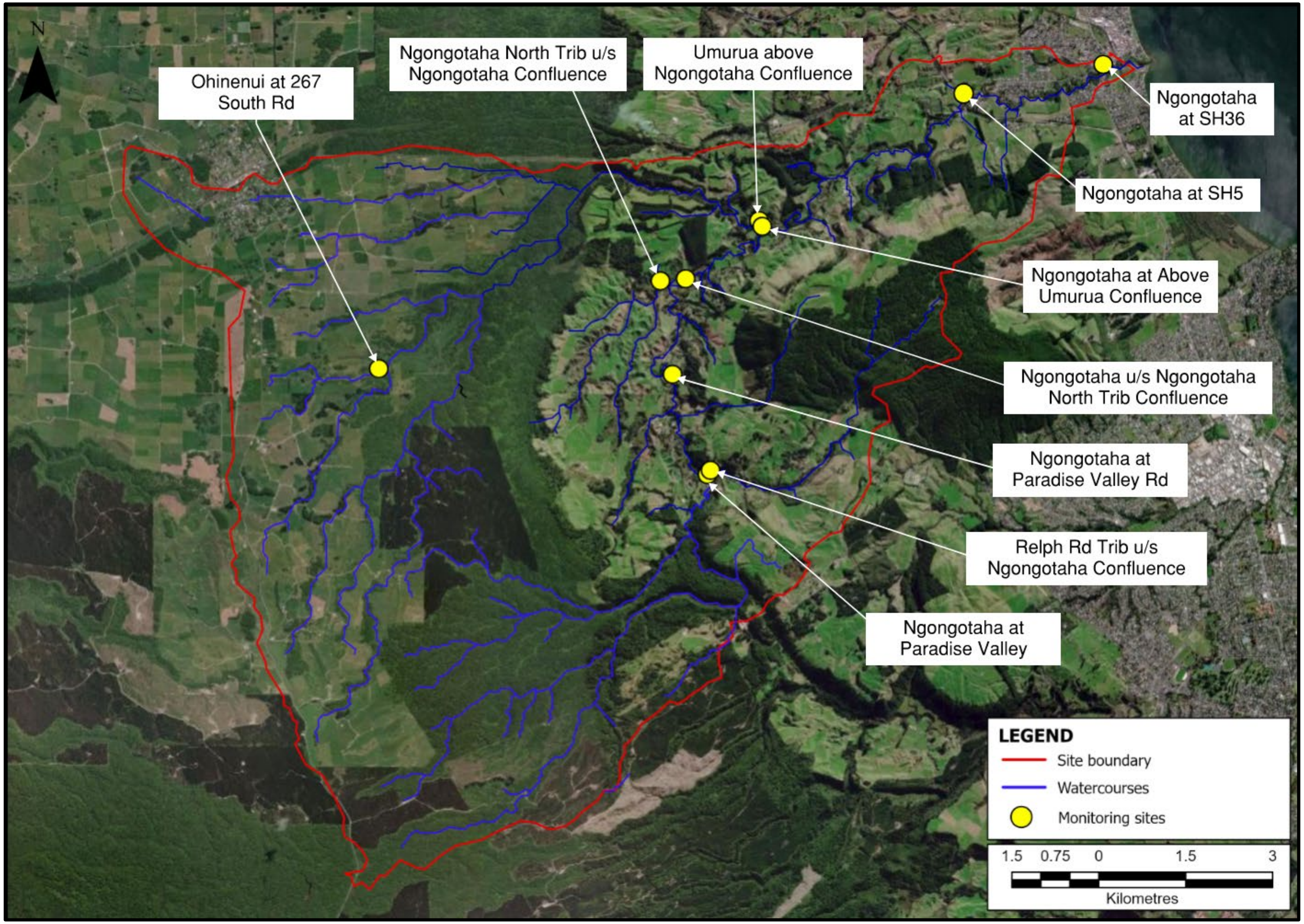

Figure 3-1. Locations of water quality and ecology NERMN sites in the Ngongotahā catchment

3.5.1 Flow Gauging

Flow was measured at each site on a number of occasions and related to continuous flow at the hydrological site (SH 5). Flow relationships for the Ngongotahā catchment were calculated using simple ratios. Discrete stream flow measurements were gauged four times over one year, targeting each major season. The gaugings for each stream were compared to the continuous flow measurements collected at the SH5 site, to create a proportion of flow / a ratio. The ratios used to relate each site to the continuous flow site are shown in Table 3-3.

Table 3-3. Ratios used to calculate proportion of flow at each site based on continuous flow measurements

Name	ID	Ratio
Ohinenui at 267 South Rd	DK178765	0.048
Umurua at U/S Ngongotahā Confluence	DK703826	0.191
Ngonogotaha North Trib u/s Ngongotahā confluence	DK562743	0.03
Relph Rd trib u/s Ngongotahā confluence	DK627492	0.016
Ngongotahā at Paradise Valley	DK618481	0.213
Ngongotahā at Paradise Valley Rd	DK574761	0.281
Ngongotahā u/s Ngongotahā North Trib confluence	DK578729	0.203
Ngongotahā at Above Umurua Confluence	DK700820	0.465
Ngongotahā at SH5	DK982984	1

3.5.2 Faecal Source Tracking

E. coli results greater than 550 cfu/100 ml were stored for faecal source tracking (FST). Samples were analysed to identify the primary sources of faecal contamination.

3.6 Results (Ngā Otinga)

3.6.1 Rainfall and Flow

Daily rainfall was recorded at the monitoring station located at Ngongotahā Stream on Relph Road. A summary of the data – summarised by month is shown in Table 3-4.

Table 3-4. Summary of daily rainfall and flow data per month in the Ngongotahā catchment (Rainfall 95th Percentile = 22 mm/day, Flow 95th Percentile = 1.81 m^3/sec).

Year	Month & Year	Number of rain days	Number of rain days > 95th Percentile	Total monthly precipitation (mm)	Number of days flow > 95th Percentile
2019	July	21	2	268.2	3
	August	21	1	170.6	4
	September	17	3	203.8	4
	October	22	3	177.9	5
	November	6	2	92.8	1
	December	11	2	232.4	2
2020	January	6	0	15.3	0
	February	7	0	14.4	0
	March	8	2	100.5	0
	April	14	0	49.3	0
	May	9	1	110.3	1

Year	Month & Year	Number of rain days	Number of rain days > 95th Percentile	Total monthly precipitation (mm)	Number of days flow > 95th Percentile
	June	18	4	272.8	4
	July	17	3	209.7	3
	August	19	2	175.5	0
	September	13	1	91.2	0
	October	12	1	70.7	0
	November	20	3	260.8	3
	December	9	0	65.3	0

The Ngongotahā catchment received significant rainfall events (>95th percentile) during most months. Of note, November 2019, March 2020 and May 2020 had < 10 rain days total, but received > 90 mm rain. Figure 3-2 shows flow and rainfall over time. Three flow events occurred in July 2019, December 2020, and June 2020 that were at least twice the calculated 95th percentile for flow. Generally, sample events coincided with periods when rainfall was less than the 95th percentile. There were only three sample events (17 October 2019, 18 November 2019, and 29 June 2020) that coincided with high flow in the continuously measured data.

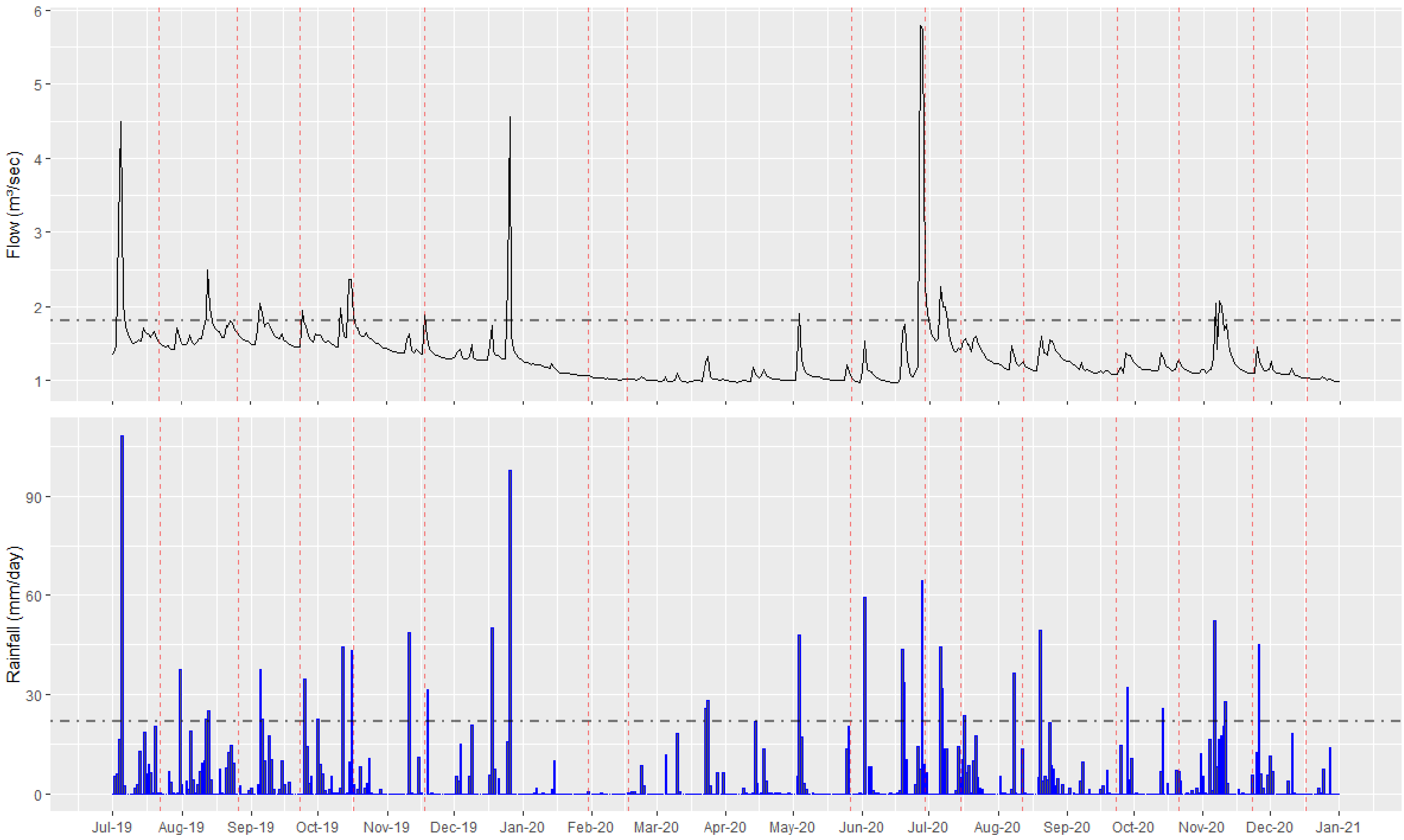

Figure 3-2. Daily flow (m3/sec) and rainfall (mm/day) in the Ngongotahā catchment. The black dashed lines represent the 95th percentile for each parameter. The vertical red dashed lines indicate days when samples were collected.

3.6.2 Conductivity

Conductivity results ranged across the catchment from a minimum of 47 µS/cm (Ngongotahā at Paradise Valley, 29 June 2020) to 92 µS/cm (Ngongotahā at Paradise Valley, 27 May 2020). The median value across all sites was 64 µS/cm. No site exceeded the guideline conductivity value for a WWL elevation or a CWH elevation (Figure 3-3).

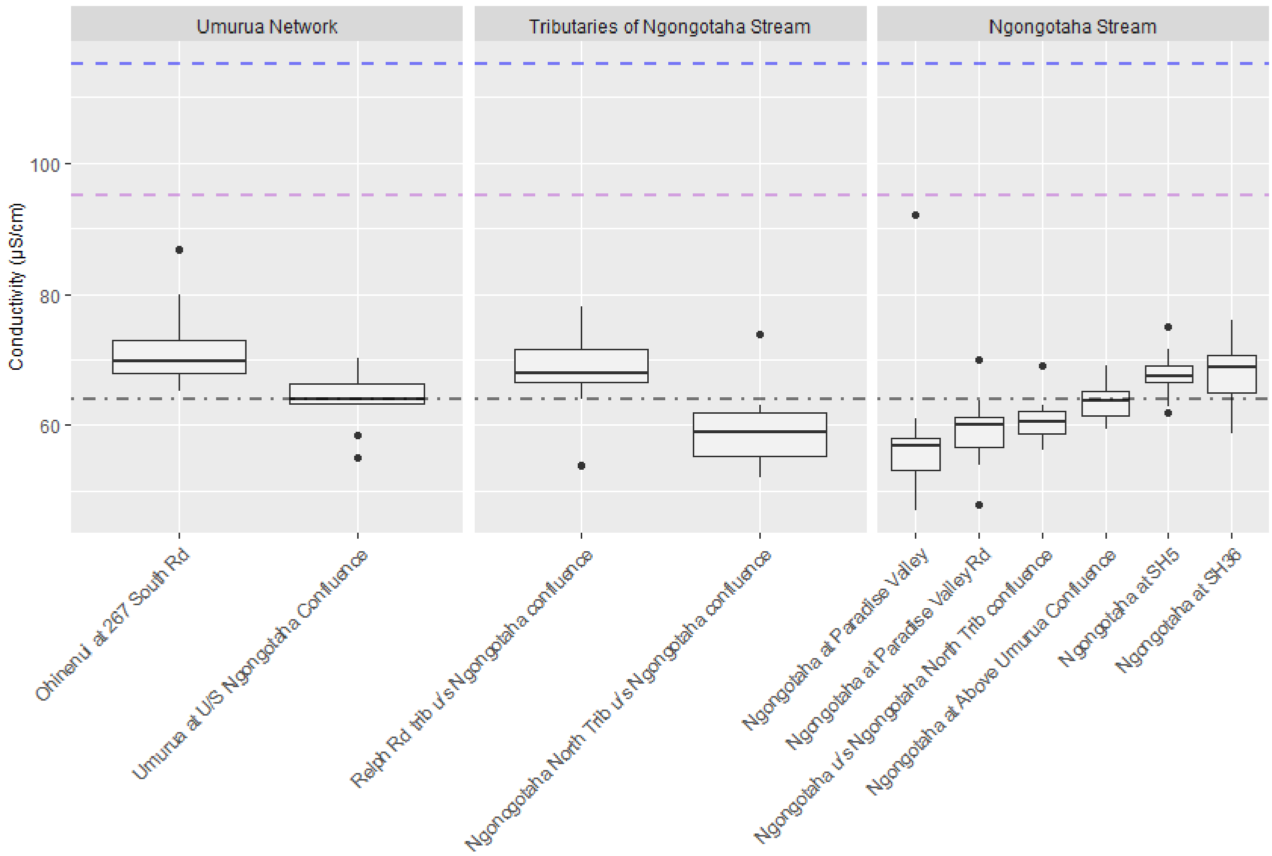

Figure 3-3. Conductivity (µs/cm) at the Ngongotahā monitoring sites between 2019 and 2020. Comparative conductivity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

3.6.3 Dissolved Oxygen

Median DO range from 101% at the top of the catchment (Ohinenui at 267 South Road), to 91% (Ngongotahā North Tributary upstream of Ngongotahā confluence). The median value across all sites was 94%. The greatest DO saturation obtained was 110% (Ngongotahā at SH5, 27 May 2020). The lowest DO saturation measured was 86% (Ngongotahā at Paradise Valley Road, 29 June 2020).

According to the ANZG designations in Table 3-23, all DO saturation levels at each site are within acceptable ranges for sites within a CWL REC. The median DO saturation at WWL sites were greater than guideline levels. However, 22% of sample events that occurred in the WWL sites did not meet DO saturation guidelines for a WWL REC.

It should be noted that the data was collected by grab sampling, and typically mid-to-late morning. Therefore, the sampling does not capture the diel cycling of DO at the sites, and would not indicate whether DO is depleted significantly at night.

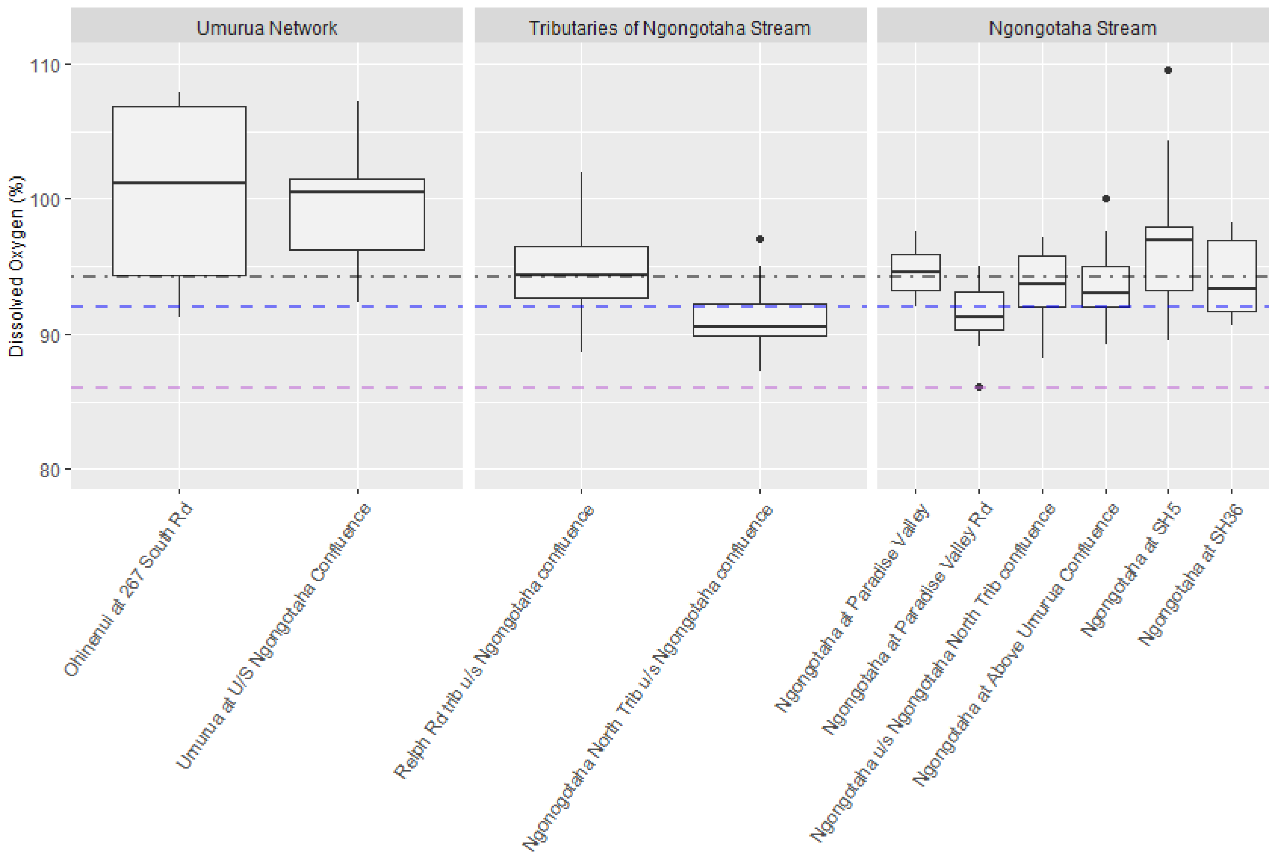

Figure 3-4. Dissolved oxygen saturation (%) measurements at the Ngongotahā monitoring sites between 2019 and 2020. Comparative conductivity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

3.6.4 Water Temperature

The median water temperature across all sites was 11.3°C. Relph Road Tributary upstream of Ngongotahā confluence demonstrated the greatest variation in temperature, with the minimum recorded temperature of 8°C (22 July 2019) and a maximum temperature of 17.9°C (30 January 2020). These values are within the normal ranges for New Zealand streams and rivers (MfE, 2021).

The Summer Cox-Rutherford index is used by BOPRC to assess upland and lowland areas (Carter, Suren & Scholes, 2017). The value for the 'A' attribute band is shown in Figure 3-5. Based on this, all sites appear to fall within the 'A' band for water temperature, both in the upland and lowland areas. The catchment is spring-fed, which likely contributes to the low overall temperature.

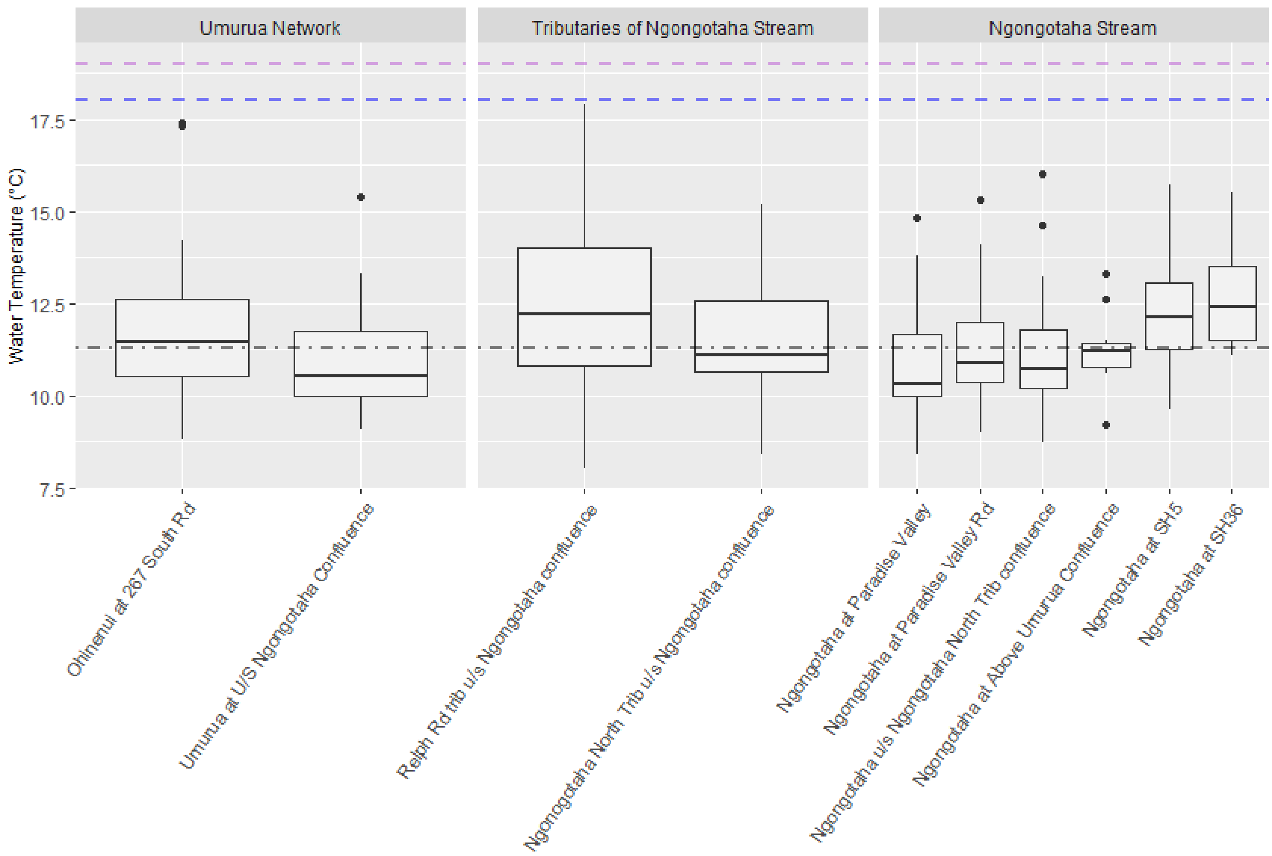

Figure 3-5. Water temperature (ºC) measurements at the Ngongotahā monitoring sites between 2019 and 2020. Comparative conductivity values shown are the catchment median (grey), and the Summer Cox-Rutherford index 'A' band temperature for lowland (blue) and upland (pink) waterways.

3.6.5 pH

pH (field) results varied across the catchment from a minimum of 6.67 pH units (Ngongotahā North Tributary upstream of Ngongotahā confluence) to a maximum of 8.25 (Ohinenui at 267 South Road). The site at Ohinenui – the most upstream site - demonstrated the greatest variation, with a difference of 1.31 pH units between its most acidic and most basic measurement. Additionally, the greater concentrations observed in the Ohinenui Stream does not meet the requirements of attribute band A for pH in water (pH 6.5-8.0, Table 2-5).

Apart from the site at Ohinenui, the median across all sites was more acidic than the WWL and CWH guideline value. However, according to a study conducted on Bay of Plenty water quality from 2014-2018, the pH range across 59 sites was 6.7-8.1, and the median pH for all lowland sites was 7.00. The median across all sites in the Ngongotahā catchment during the 2019-2020 monitoring period was 7.11.

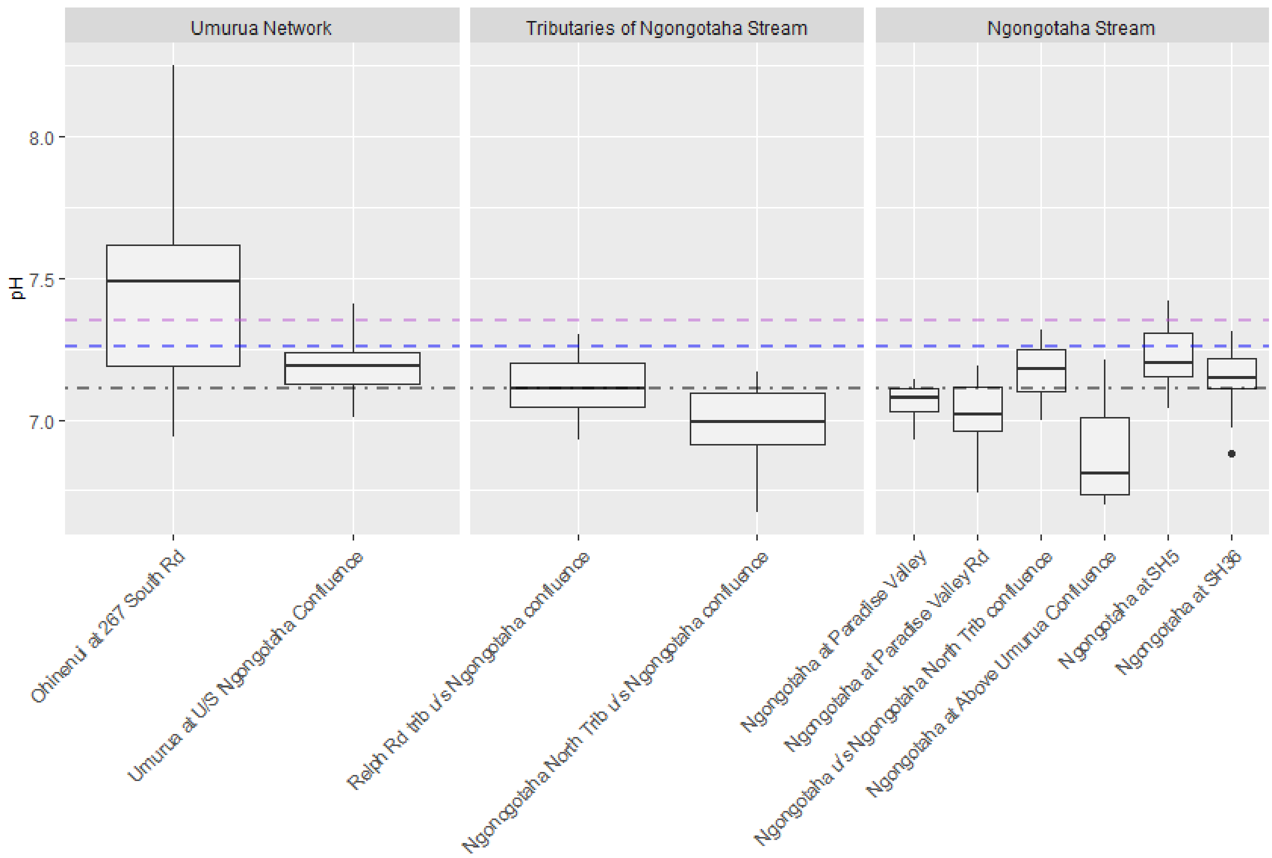

Figure 3-6. pH measurements at the Ngongotahā monitoring sites between 2019 and 2020. Comparative conductivity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

3.6.6 Turbidity

Turbidity results varied across the catchment from a minimum of 0.7 NTU (Ngongotahā at Paradise Valley, 21 October 2020) to a maximum of 124 NTU (Ohinenui at 267 South Road, 18 November 2019). The median for each site was below the WWL guideline value, however, 50% of hill sites are at/or above the CWH guideline value. The median for all sites in the Ngongotahā catchment during the 2019-2020 monitoring period is 2.4 which meets the CWH guideline value.

The sample event that occurred at Ohinenui at 267 South Road on the 18 November 2019 had significantly greater turbidity than all other results from the location and the wider catchment. The next largest value was 43 NTU (Relph Road Tributary u/s Ngongotahā Confluence, 18 November 2019), which was obtained on the same day within a different tributary. Approximately 60 mm rainfall had occurred in the week prior to the sample event, which may have caused a slip in the area / upslope of the area. The land area is classified as ‘steep hill country’. Therefore, this terrain may pose an increased erosion risk during periods of rainfall.

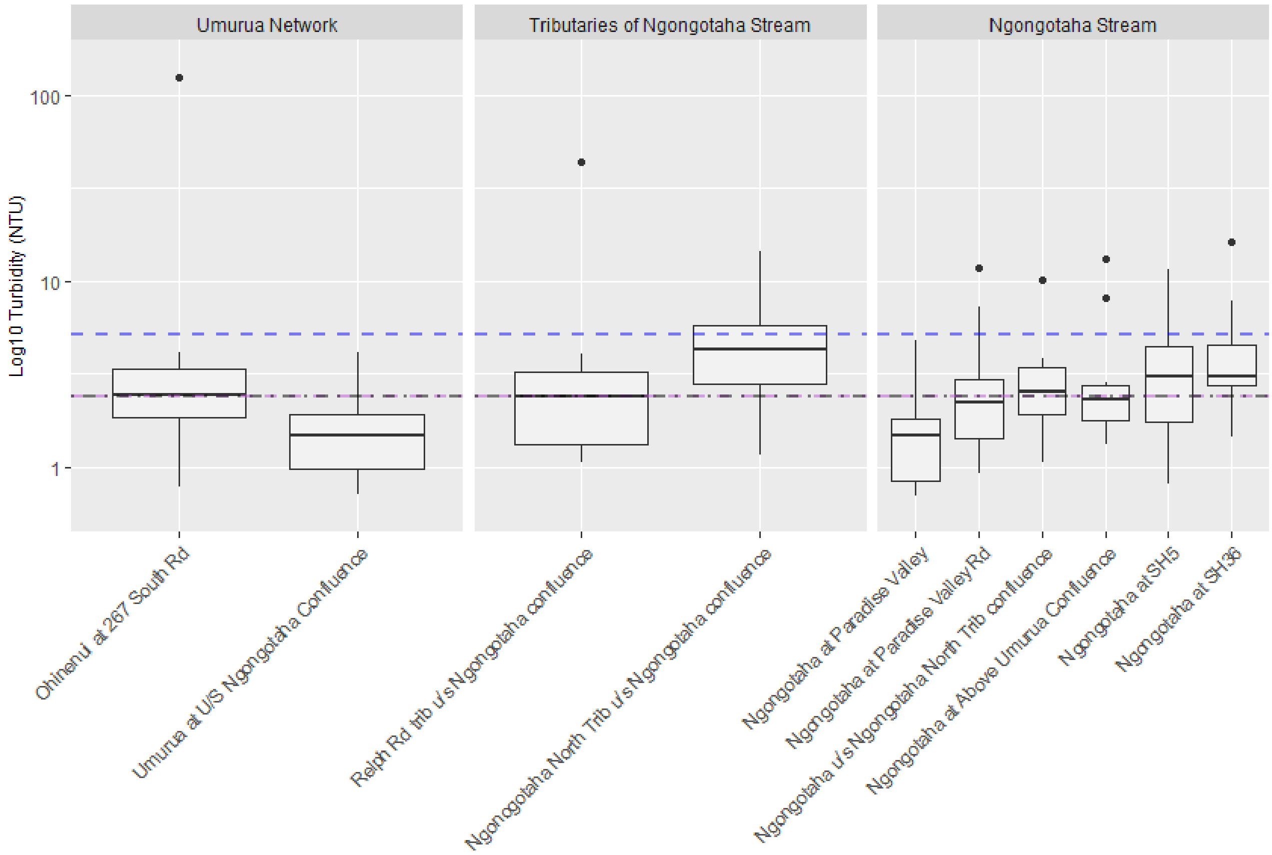

Figure 3-7. Turbidity (NTU) measurements at the Ngongotahā monitoring sites between 2019 and 2020. Comparative conductivity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink). Please note, the median and ANZG for cool wet hill country are the same value, and the pink line is obscured.

3.6.7 *E. coli* Concentration – All Monitoring Sites

In general, the median *E. coli* concentrations in the Ngongotahā catchment are within the acceptable range, except for the monitoring site at Ohinenui at 267 South Road, which had a median *E. coli* concentration in the 'Alert/Amber' range. The 95th percentile data for nine of the ten monitoring sites are higher than the Red/Action threshold over the 2019 to 2020 period. A majority of the 95th percentile data from the monitoring sites coincide with rainfall events. Six of these data were from the same sample event (18 November 2019). Approximately 61 mm of rain had been recorded in the catchment in the week prior to the sample event. Similarly, a sample with high *E. coli* concentrations was collected on 29 June 2020. There was elevated rainfall recorded on this day (9 mm), and on the day prior (65 mm).

However, the 95th percentile data for the Ngongotahā Stream and the North Tributary directly upstream of their confluence contain elevated *E. coli* than do not coincide with similarly elevated rainfall events or high synthetic flow estimates. These samples were also collected on the same day (17 February 2020). The site at Ohinenui at 267 South Road is the most western (upgradient) monitoring site in the catchment and is within indigenous forest. Therefore, it would be expected that this site would have the lowest *E. coli* concentration, as the effects of exotic grassland and anthropogenic activity are occurring downstream. However, this site had the highest mean *E. coli* concentration over the monitoring period.

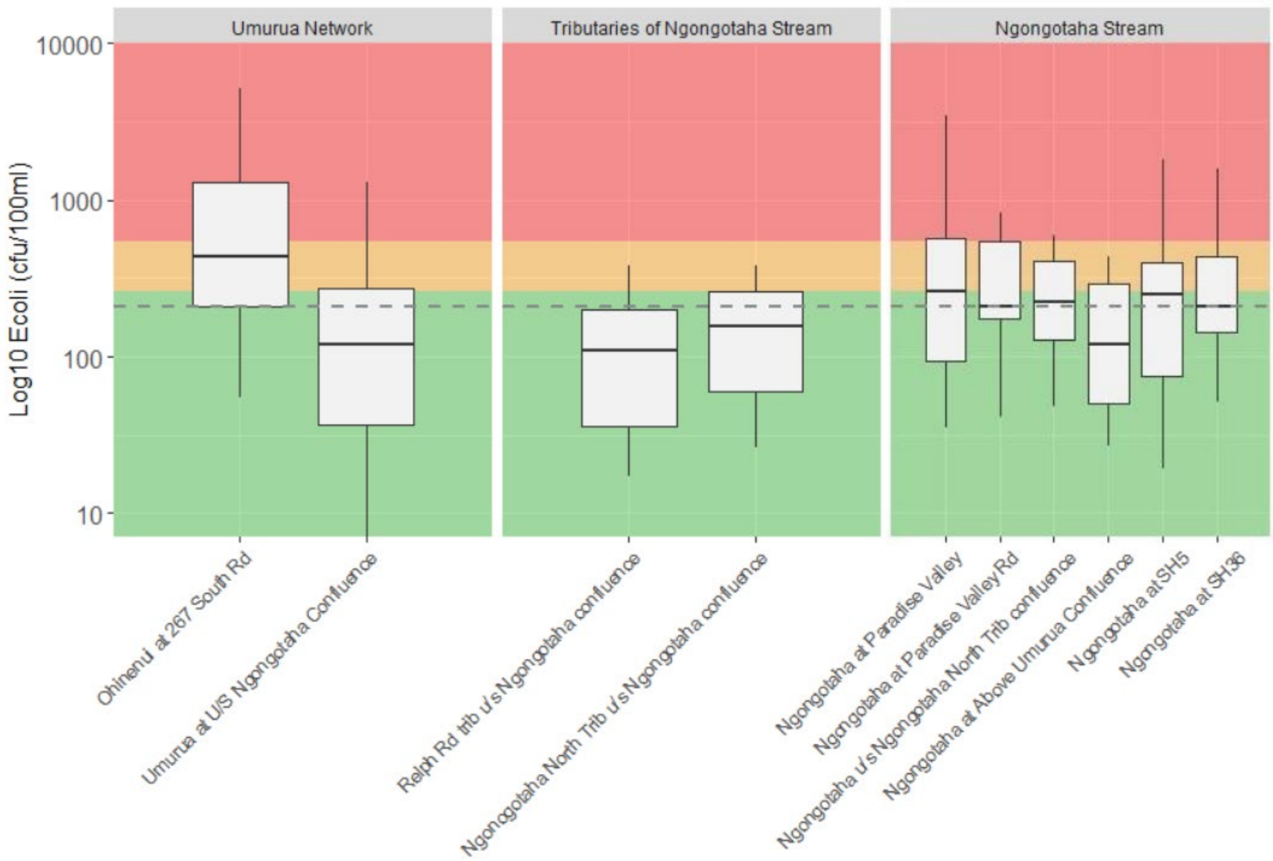

Figure 3-8. *E. coli* (cfu/100 mL) measurements at the Ngongotahā monitoring sites between 2019 and 2020. The catchment median is indicated by the grey dashed line.

For the purposes of assessing the temporal variability of *E. coli* concentrations, the concentrations were divided into 'summer' (i.e. November to April) and 'winter' (i.e. May-October) periods. The allocation of months to 'winter' and 'summer' is based on previous reporting (Mahon et al., 2020) and matches the summer period in the NPSFM. The median relative *E. coli* concentrations in summer and winter were explored in the form of heat/bubble maps, which can be viewed in Figure 3-9 and Figure 3-10. The colour of the 'bubbles' in the figures indicate which category each monitoring site falls into, on average. The relative size of the 'bubbles' is an arbitrary indication of the 'size' of the concentration within each category.

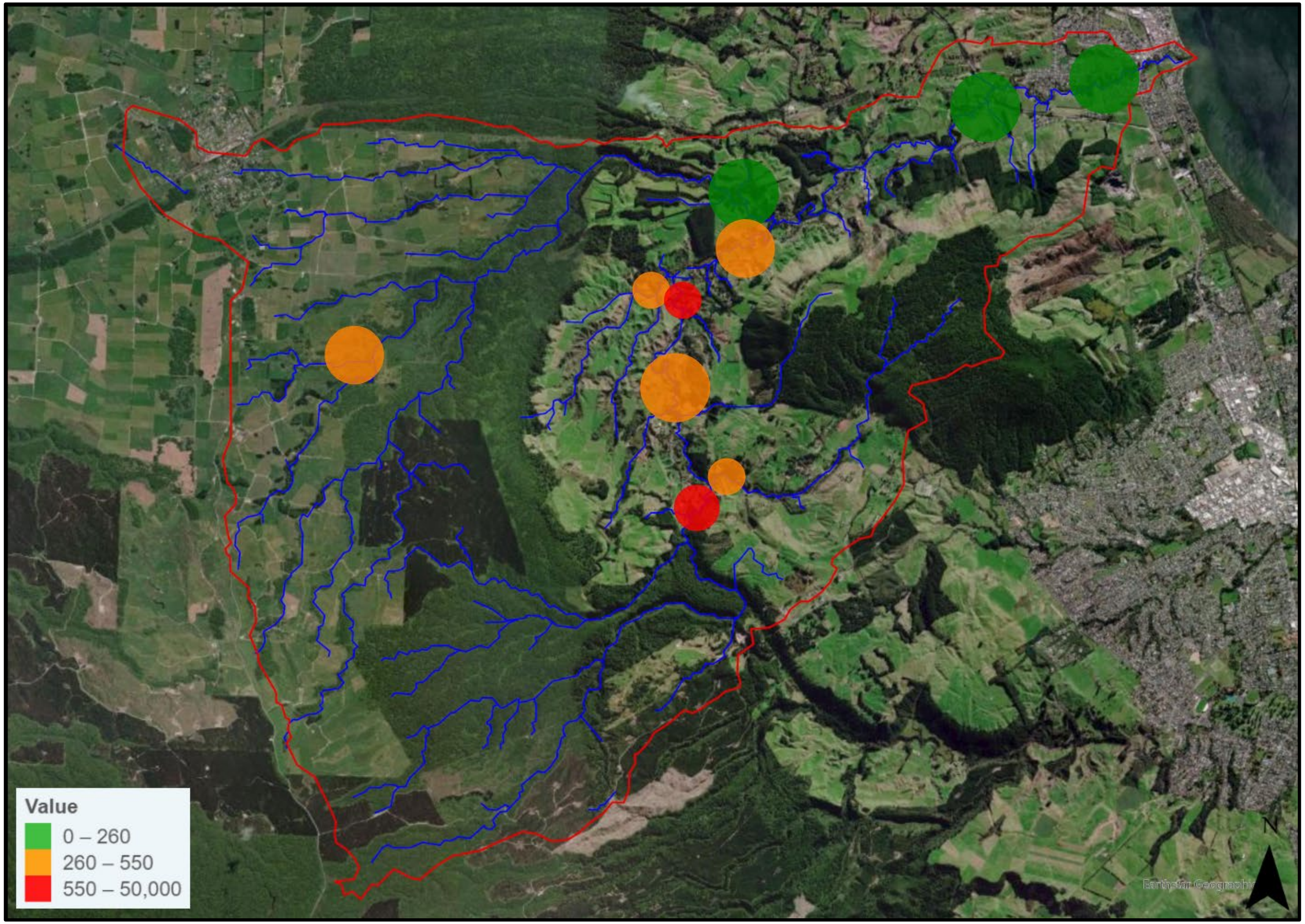

Figure 3-9. A heat map for median relative *E. coli* concentrations (cfu/100 mL) per site in the summer period (November-April) in the Ngongotahā catchment. Green indicates 'Acceptable', orange indicates 'Alert', and red indicates 'unsafe' according to the MWQG (2003). The size of the circles at each location indicate the 'size' of concentration value within each concentration range, based on arbitraty divisions of concentrations within each *E. coli* concentration range.

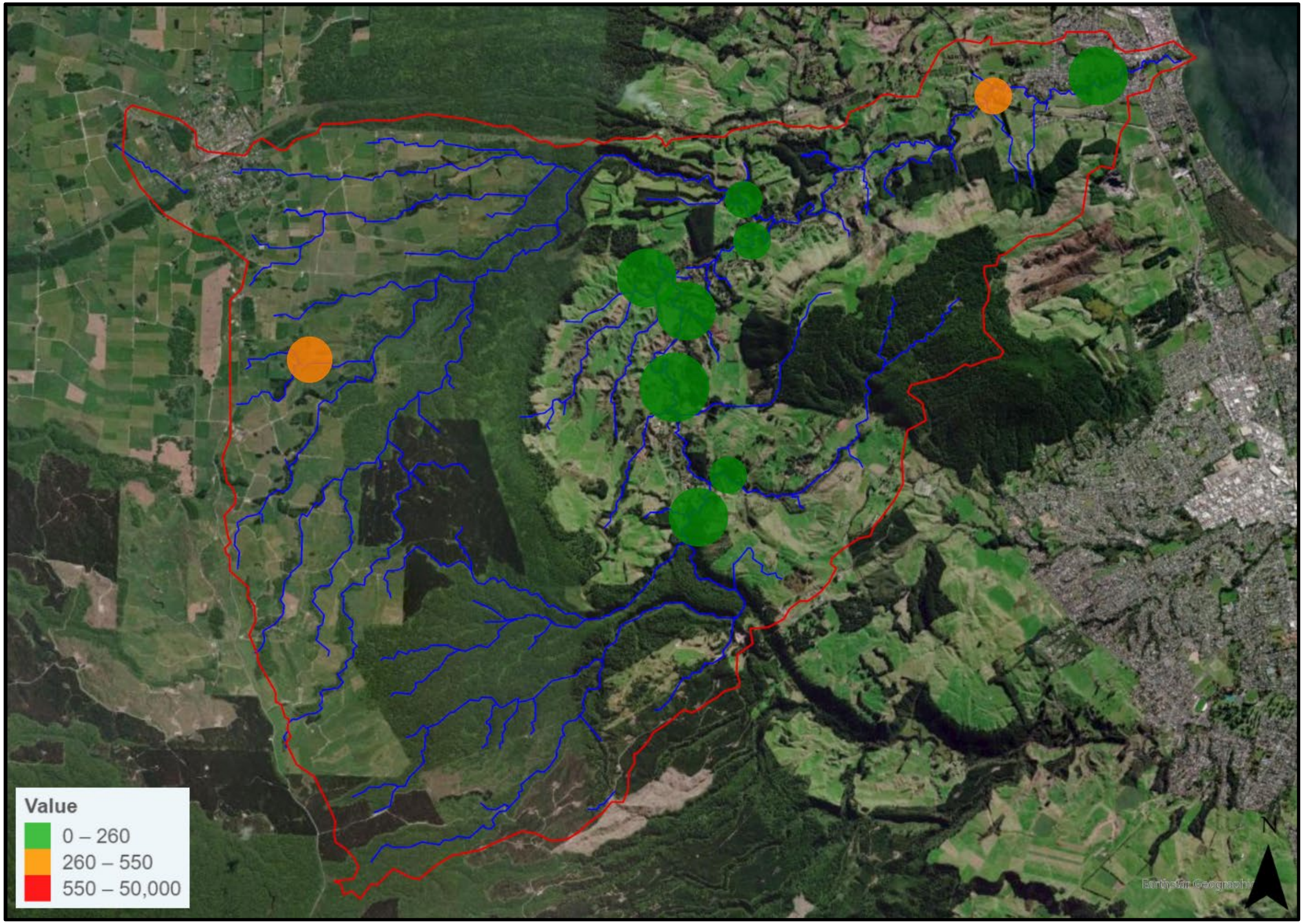

Figure 3-10. A heat map for median relative *E. coli* concentrations (cfu/100 mL) per site in the winter period (May-October) in the Ngongotahā catchment. Green indicates 'Acceptable', orange indicates 'Alert', and red indicates 'unsafe' according to the MWQG (2003). The size of the circles at each location indicate the 'size' of concentration value within each concentration range, based on arbitraty divisions of concentrations within each *E. coli* concentration range.

Based on data from the summer period (Figure 3-9), the monitoring stations in the upper catchment show greater median concentrations of *E. coli*, and fall within the ‘Alert’ to ‘Unsafe’ range. However, in the winter months (Figure 3-10), only the most upstream site and one of the most downstream sites do not fall in the ‘Acceptable’ range.

The percentage of events within each category per season, across the whole catchment, is shown in Figure 3-11. When assessing by season, it appears that a much larger percentage of events fall into the Amber or Red categories over the summer months. This is expected, as the summer period typically exhibits lower rainfall and lower flow than the winter period (Table 3-4) (Whitehead, Depree & Quinn, 2019). While contributions overall may be greater in the winter periods (e.g. due to transport via overland flow), there is greater average rainfall and flow to dilute the contributions. Exceedances in the summer period are particularly of note, as this is the period in which the community would be likely to seek out swimming spots.

When comparing ‘summer’ versus ‘winter’ sampling flow and loads, there are two factors to consider. The first is that winter conditions are more likely to dilute nutrient and faecal inputs. The second is that the summer period is more likely to represent ‘baseflow’ conditions, which is the streamflow that is sustained between precipitation events and is fed by alternate / delayed pathways. The greater concentrations during the summer/baseflow periods may indicate that there is both diffuse runoff (i.e. faecal material transported in runoff) and direct deposition occurring in the catchment.

Figure 3-11. Percentage of sample events that fall within each *E. coli* category, categorised as summer (November-April, n=40) and winter (May-October, n=93).

3.6.8 FST

If *E. coli* concentrations exceeded 550 cfu/100mL, FST was carried out. Table 3-5 lists the likely source of faecal contamination in water. The primary source of faecal contamination appears to be ruminant in 11 of the 14 events. There were also avian sources recorded in the Ngongotahā Stream at Paradise Valley (one of the most upstream sites) and Paradise Valley Road (downstream of Ngongotaha at Paradise Valley). Both ruminant and avian sources were recorded on one occasion at Ngongotahā at SH36, and at SH5, which are the most downstream sites.

3.6.9 *E. coli* Load

The *E. coli* load has been expressed as the contaminant mass (cfu) per unit of time (seconds). Figure 3-12 shows a box and whisker plot of the load estimates over 2018 to 2021, based on the proportional relationships presented in Table 3-3.

As anticipated, the site with the highest (worst) median and maximum load was the Ngongotahā stream at SH5, followed by the Ngongotahā stream at SH36. These are the most downstream sites, receiving the cumulative *E. coli* load from all other sites plotted. The loading from the most upstream site (Ohinenui at 267 South Road) is comparatively lower (better), despite having the greatest median *E. coli* concentration (Figure 3-8).

The Ngongotahā stream itself typically had a median between 6.3 x 10^6 cfu/s (Paradise Valley) and 6.5 x10^6 cfu/s (SH5) at each monitoring station along its length. The other streams and tributaries that converge with Ngongotahā (e.g. Umurua, North Tributary, Relph Road) demonstrated lower median *E. coli* loads (Load < 9.1 x 10^5 cfu/s) – an order of magnitude less. Therefore, while the other branches are contributing to the total *E. coli* load, they do not appear to be the primary/initial sources of *E. coli* to the Ngongotahā Stream.

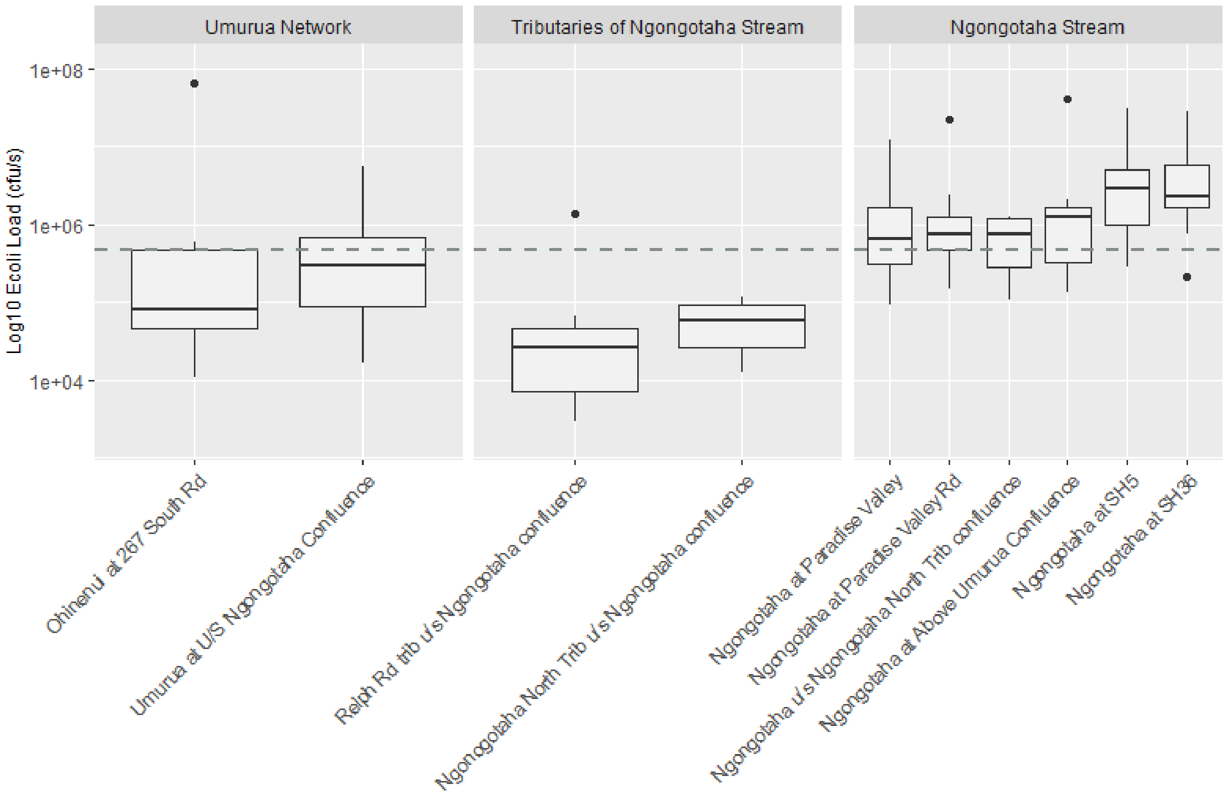

Figure 3-12. E. coli (cfu/100 mL) measurements at the Ngongotahā monitoring sites between 2019 and 2020. Note y-axis has log10 scale.

Table 3-5. Faecal source tracking results for water samples that contained E. coli >550 cfu/100mL.

Site Name	Date	Original Result	Human Contamination	Ruminant Contamination	Proportion Ruminant	Sheep	Cow	Dog	Avian	Conclusion
Ohinenui at 267 South Rd	22/07/2019	2200	No	Yes	50-100%	Yes	No	No	No	Ruminant source (50-100%) - sheep.
Ngongotahā at Paradise Valley	18/11/2019	3500	No	Yes	10-50%	Yes	No	No	Yes	Ruminant source (10-50%) - sheep.
Ngongotahā at Paradise Valley Rd	18/11/2019	6000	No	Yes	50-100%	No	No	No	No	Ruminant source (50-100%) - unknown.
Ngongotahā at Above Umurua Confluence	18/11/2019	5300	No	Yes	50-100%	No	No	No	No	Ruminant source (50-100%) - unknown.
Umurua at U/S Ngongotahā Confluence	18/11/2019	590	No	Yes	10-50%	NA	NA	No	No	Ruminant source (10-50%) - unknown.
Ngongotahā at SH5	18/11/2019	1800	No	Yes	1-10%	NA	NA	No	Yes	Ruminant source - unknown (1-10%) & Avian source.
Ohinenui at 267 South Rd	18/11/2019	100000	No	Yes	50-100%	No	Yes	No	No	Ruminant source (50-100%) - cow.
Ngongotahā at SH36	18/11/2019	1600	No	Yes	50-100%	No	No	No	Yes	Ruminant source - unknown (50-100%) & Avian source.
Ngongotahā at Paradise Valley	30/01/2020	660	No	No	NA	NA	NA	No	Yes	Avian Source
Ngongotahā at Paradise Valley Rd	17/02/2020	830	No	Yes	1-10%	NA	NA	No	Yes	Ruminant source (1-10%) & Avian
Umurua at U/S Ngongotahā Confluence	6/07/2020	1000	No	Yes	50-100%	NA	NA	No	No	Ruminant source (50-100%) - unknown.
Ngongotahā at SH5	6/07/2020	55000	No	Yes	50-100%	NA	NA	No	No	Ruminant source (50-100%) - unknown.
Ngongotahā at Paradise Valley	15/07/2020	1300	No	No	NA	NA	NA	No	Yes	Avian Source
Ngongotahā at Paradise Valley Rd	15/07/2020	800	No	No	NA	NA	NA	No	Yes	Avian Source - very low levels

3.6.10 *Swimming Site E. coli* Concentrations - Ngongotahā at Railway Bridge & Lake Rotorua at Ngongotahā

The two primary recreational sites within this catchment are downstream of the sample location on Ngongotahā Stream at SH36. Therefore, the data collected from this location will be used to establish the status of the swimming sites.

Across the 14 sample events that occurred in the Ngongotahā Stream at SH36, 64% of *E. coli* concentrations were considered acceptable for swimming. The remainder of sample events indicated that caution should be advised, or the site is not safe for swimming (Table 3-6).

Table 3-6. Proportion of events within each MWQG category for *E. coli*.

MWQG Threshold / Implication	MWQG Numerical Value	Percentage of Events	Number of Events
Acceptable / Safe for swimming	<260 cfu/100 mL	64%	9
Alert / Caution Advised	260-550 cfu/100 mL	14%	2
Action / Unsafe for swimming	>550 cfu/100 mL	21%	3
Total number of events			**14**

The NPSFM 2020 provides attribute bands based on the percentage of exceedances (MfE, 2020). For each attribute band, there is a predicted average *Campylobacter* infection risk. From the results presented in Table 3-6, the swimming site appears to fall within attribute band D (orange), as the number of events with *E. coli* > 540 cfu/100 mL is greater than 20%, and the median concentration is > 130 cfu/100 mL. In attribute band D, the predicted average infection risk is >3%.

Table 3-7. Classification of the swimming site over the monitoring period (July 2019 – December 2020).

% Exceedances > 540 cfu/100 mL	% Exceedances > 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th Percentile (cfu/100 mL)	Attribute Band
21%	35%	210	1600	D (orange)

3.7 Discussion (Matapakitanga)

35% of samples collected from the Ngongotahā swimming site (i.e. Ngongotahā Stream at SH36) do not meet ‘acceptable/green’ threshold values for *E. coli.* It appears that the *E. coli* concentrations are already elevated at the most upstream site on the Ngongotahā network.

This site (Ohinenui at 267 South Road) is in an area of intensive farmland, which appears to be affecting water quality from the top of the catchment, particularly as the primary identified source of faecal contamination was ruminants (sheep and cows). This site was also adjacent to a pig farm that was active during the monitoring period, and received fines for poor farm management and effluent discharges directly to water (BOPRC, 2022; Griffiths, 2022). However, we understand that this farm closed in January 2022 (Braden Rowson, Pers. Comms., 2 September 2022; Environment Court New Zealand, 2022). The effects of closing the pig farm site are not quantified in the dataset and would require more present-day monitoring to establish whether there is an overall improvement at the site as a result of the retirement of this type of land use. It would be beneficial to continue monitoring faecal source and concentrations in some capacity, particularly to identify whether the closure reduces *E. coli* concentrations overall downstream.

While the median concentrations at this site are within the ‘alert/amber’ range, the site contributes one of the lowest *E. coli* loads (Figure 3-12) due to the low flow in this area. The Ngongotahā Stream at Paradise Valley is the most upstream sample location on the Ngongotahā Stream. It also has elevated mean *E. coli* concentrations above the ‘alert/amber’ threshold. However, unlike the site on the Ohinenui Stream, the

Ngongotahā Stream at Paradise Valley site delivers a greater *E. coli* load, which is sustained across all Ngongotahā Stream sample sites. Its maximum recorded *E. coli* concentration and load are the second and third highest in the catchment, respectively. Therefore, this is another example of the *E. coli* source being located upstream in the Ngongotahā network, with the contributions from other confluences appearing to be secondary.

An observation is that the Ngongotahā Stream at Paradise Valley is directly downstream of a wildlife park. The park contains animal facilities, housing goats, alpaca, pigs, sheep, an aviary, and a waterfowl pond / wetland adjacent to the Stream itself. There were ruminant and avian sources identified at the Paradise Valley site in the FST analysis. Therefore, it should be considered whether this sample location is affected by the wildlife park and the animals there. It may be beneficial to establish a sample site upstream of the wildlife park, to quantify *E. coli* loading without the potential influence of the wildlife park. Additionally, it may be prudent to conduct a site walkover of the wildlife park, to assess whether there may be a potential faecal source at the site. The layout of this park, as well as the location of the Paradise Valley site, is shown in Figure 3-13.

Figure 3-13. The wildlife park and the Ngongotahā Stream sample location.

3.8 Recommendations (Whakakapinga / Ngā Tūtohutanga)

The Ngongotahā Stream conveys greater *E. coli* loads compared to the other streams and tributaries that join with it. It does appear that water quality is already affected at the upper monitoring sites, which suggests that lowland activities are not the primary source, or primary area to be targeted by mitigation strategies.

Recommendations for further assessment are as follows:

i. **Continue monitoring to assess whether the piggery closure has had an effect on catchment water quality.**

A pig farm that was allowing effluent to directly enter the Ngongotaha network was closed, which may affect the recommendations of the present results. The effects of closing the piggery on water quality has not been quantified, as monitoring concluded prior to its closure.

ii. **Establish monitoring sites on the western perimeter of the Ngongotahā catchment to provide greater resolution of potential *E. coli* sources**

The monitoring data indicates that the source of *E. coli* loading is in the upper reaches of the Ngongotahā catchment, affecting the Ngongotahā Stream and Ohinenui Stream prior to monitoring sites. It is recommended that monitoring occurs in the upper reaches of the Ohinenui Stream and Ngongotahā Stream. In doing so, the effects of the upslope agricultural activities may be isolated and identified.

iii. **Provide education and services to encourage the protection of waterways (e.g. fencing, stock exclusion, bridges), and continue monitoring to assess whether introducing these measures / inhibiting direct deposition into waterways reduces *E. coli* loads during the summer period.**

Currently, there is a greater percentage of sample events in the allocated summer period that exceed Amber or Red *E. coli* thresholds, and there are very few sample events in the winter period that exceed these thresholds. This may be due to the effects of dilution in winter, or may indicate that direct deposition of faecal matter is occurring within waterways. By encouraging stock exclusion from waterways, future *E. coli* monitoring can be used to assess whether direct deposition was a primary contributor, or whether diffuse sources are still contributing significant *E. coli* loads during summer.

iv. **Assess the activities at / upstream of the Paradise Valley wildlife park**

The Ngongotahā Stream monitoring site at Paradise Valley is located downstream of a wildlife park with grazing animals and a waterfowl wetland. Viewing/assessing the site and its activities may be beneficial to identify potential sources of faecal contamination in the waterway (e.g. waterfowl nesting areas, the sheep facilities).

v. **Establish a monitoring site upstream of the Paradise Valley wildlife park**

If the site walkover of the park and activities is inconclusive, it may be necessary to establish the monitoring site for *E. coli* concentration and FST upstream of the wildlife park, to eliminate the potential effects of the park on results.

vi. **Explore the costs and benefits of a more bespoke public health risk model for the Ngongotaha catchment and wider Rotorua area.**

With the existing *E. coli* database, it may be beneficial to investigate a bespoke Quantitative Microbial Risk Assessment (QMRA) for the relative health risk posed by *E. coli* exposure at swimming sites. Currently, a generalised public health system assessment is utilised in the Rotorua region to assess swimmability and safety. However, it may be beneficial to use the data collected establish a relative target for the swimming sites that, on balance, is achievable and low risk to the public.

Beyond the characterisation of the Ngongotahā catchment, the following assessments may be beneficial in the future, but are not pertinent to present characterisation and mitigation of waterways in the Ngongotahā catchment.

- Investigate potential *E. coli* contributions in groundwater and/or interflow from adjacent upslope catchments into the Ngongotahā catchment. The well-drained, productive land upslope / outside of the Ngongotaha catchment may be a source of contamination in the headwaters of the Ohinenui and Ngongotaha streams via overland flow, near-surface transport, or groundwater flow. An assessment of the subsurface gradient may provide information on the source of contamination within the catchment.
- Investigate the potential extent of *E. coli* transmission via porous volcanic soils.

3.9 Conclusions

The Ngongotahā Stream swimming site at Railway Bridge regularly exceeds accepted swimmability standards for *E. coli* in water, and statistics indicated that the quality was degrading further during a swimming site assessment in 2020[5]. Monitoring has been carried out across the catchment in order to identify the source of faecal contamination and inform further actions, to improve water quality enough to reduce downstream effects at swimming sites.

The data suggests that the upslope activities in the Ngongotahā catchment are affecting the catchment water quality. The Ngongotahā Stream consistently conveyed a more elevated load of *E. coli* than the streams that connect with it, and the upstream sites of the Ngongotahā Stream and Ohinenui Stream show evidence of elevated concentrations, despite their upstream location in the catchment. Therefore, to improve downstream quality, the upper catchment may require more intensive assessment and sampling, so that targeted mitigation can occur at the identified source.

Depending on the findings of the assessment, future investigations may include quantifying potential contributions from the Mamaku Plateau to the west (outside of the Ngongotahā catchment).

[5] Dare, J. (October 2020). Recreational Waters Surveillance Report. BOPRC, Whakatāne.

Appendix A1: Ngongotahā Catchment

Overall Summary Statistics

Table A-1. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max	SE mean
Ammoniacal N (g/m^3)	134	0	0.007	0.01	0.01288	0.01515	0.186	0.00146944
Conductivity (us/cm)	134	46.9	59.15	63.95	64.12	68.88	92	0.6179976
DO Sat (%)	133	86.1	91.7	94.2	95	96.9	109.5	0.4027793
DRP (g/m^3)	133	0.002	0.009	0.014	0.01893	0.026	0.195	0.001647058
E coli (g/m^3)	133	7	61	210	483.6	440	6000	0.8564037
N total (g/m^3)	133	0.3906	0.7293	0.82	0.9283	0.9040	9.0839	0.06864007
Nitrate nitrate (as N) (g/m^3)	133	0.2810	0.64301	0.7180	0.7345	0.8150	1.5081	0.01765395
O_2 (g/m^3)	133	9.02	9.93	10.27	10.25	10.58	12.48	0.05114963
Total P (g/m^3)	134	0.01160	0.02063	0.03380	0.04309	0.046	0.853	0.00648724
pH	134	6.67	7.02	7.11	7.131	7.21	8.25	0.0192105
Total suspended solids (g/m^3)	134	0.4444	2.8	4.225	8.3145	6.9	140	1.3449081
Turbidity (NTU)	134	0.706	1.55	2.4	4.380	3.478	124	0.9784332
Water Temperature (°C)	133	8.0	10.5	11.3	11.76	12.8	17.9	0.1724799

Ohinenui at 267 South Road

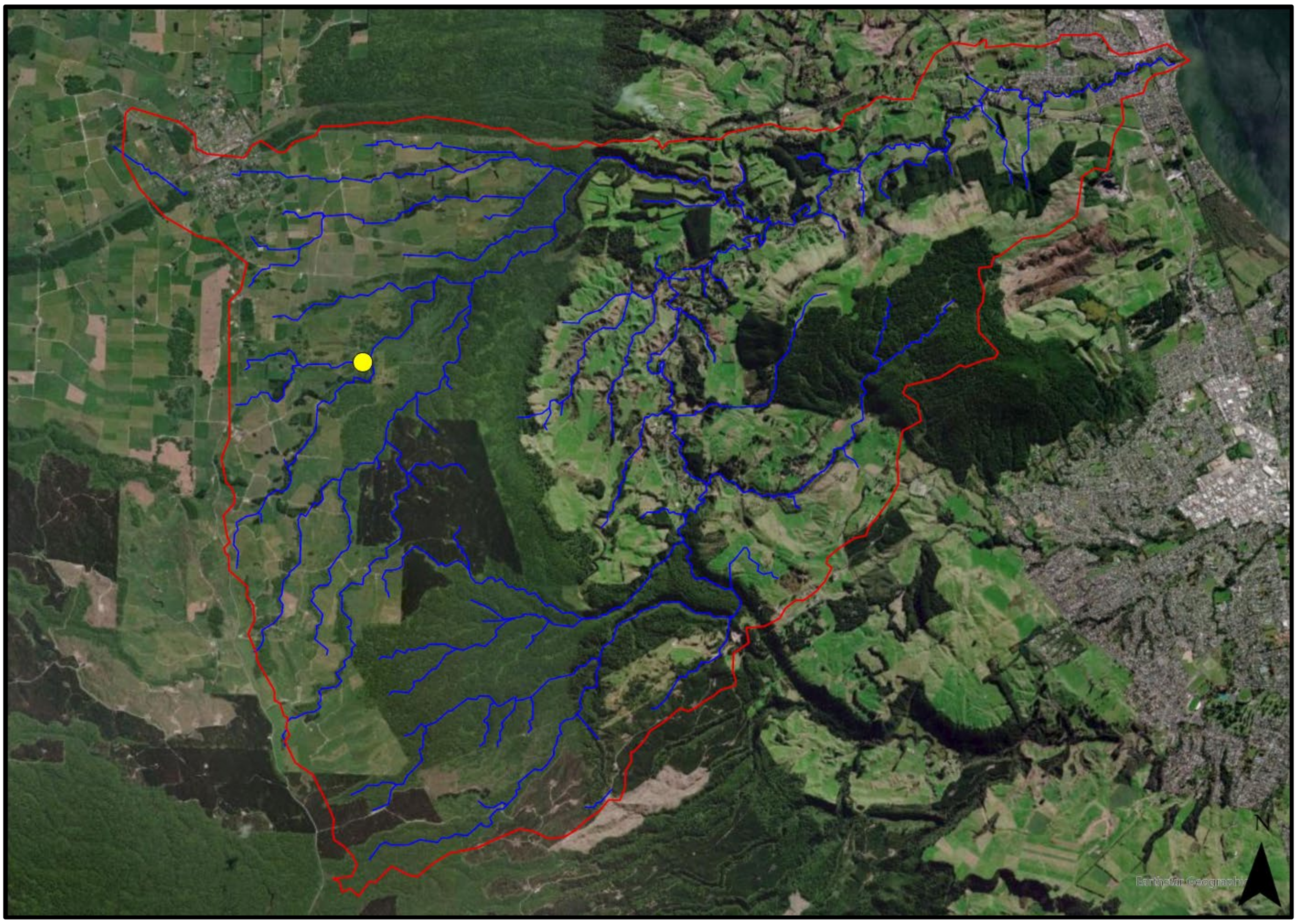

Figure A-1. Location of Ohinenui at 267 South Road in the Ngongotahā Catchment

Summary statistics

Table A-2. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	14	0	0.00563	0.00805	0.02711	0.022	0.186
Conductivity (us/cm)	14	65.1	68	69.75	71.71	73	86.7
DO Sat (%)	14	91.2	94.33	101.15	100.46	106.9	107.9
DRP (g/m^3)	14	0.0086	0.0135	0.0162	0.03455	0.02337	0.195
E coli (g/m^3)	13	55	210	440	984	1300	5200
N total (g/m^3)	14	1.101	1.266	1.398	2.104	1.684	9.084
Nitrate nitrate (as N) (g/m^3)	14	0.708	1.002	1.075	1.083	1.186	1.508
O_2 (g/m^3)	14	9.35	10.34	10.71	10.69	10.98	11.69
Total P (g/m^3)	14	0.0179	0.03925	0.0555	0.12502	0.07510	0.853
pH	14	6.94	7.19	7.49	7.491	7.615	8.25
Total suspended solids (g/m^3)	14	0.8889	2.7059	3.9333	18.7533	4.7	140
Turbidity (NTU)	14	0.785	1.84	2.435	11.117	3.36	124
Water Temperature (^oC)	14	8.8	10.53	11.45	12.16	12.60	17.4

State of the site

Microbiological guidelines assessment

Table A-3 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-3. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	3	440	0	3	0
Winter	10	365	4	2	4
All samples	13	440	4	5	4

Ngongotahā at Paradise Valley

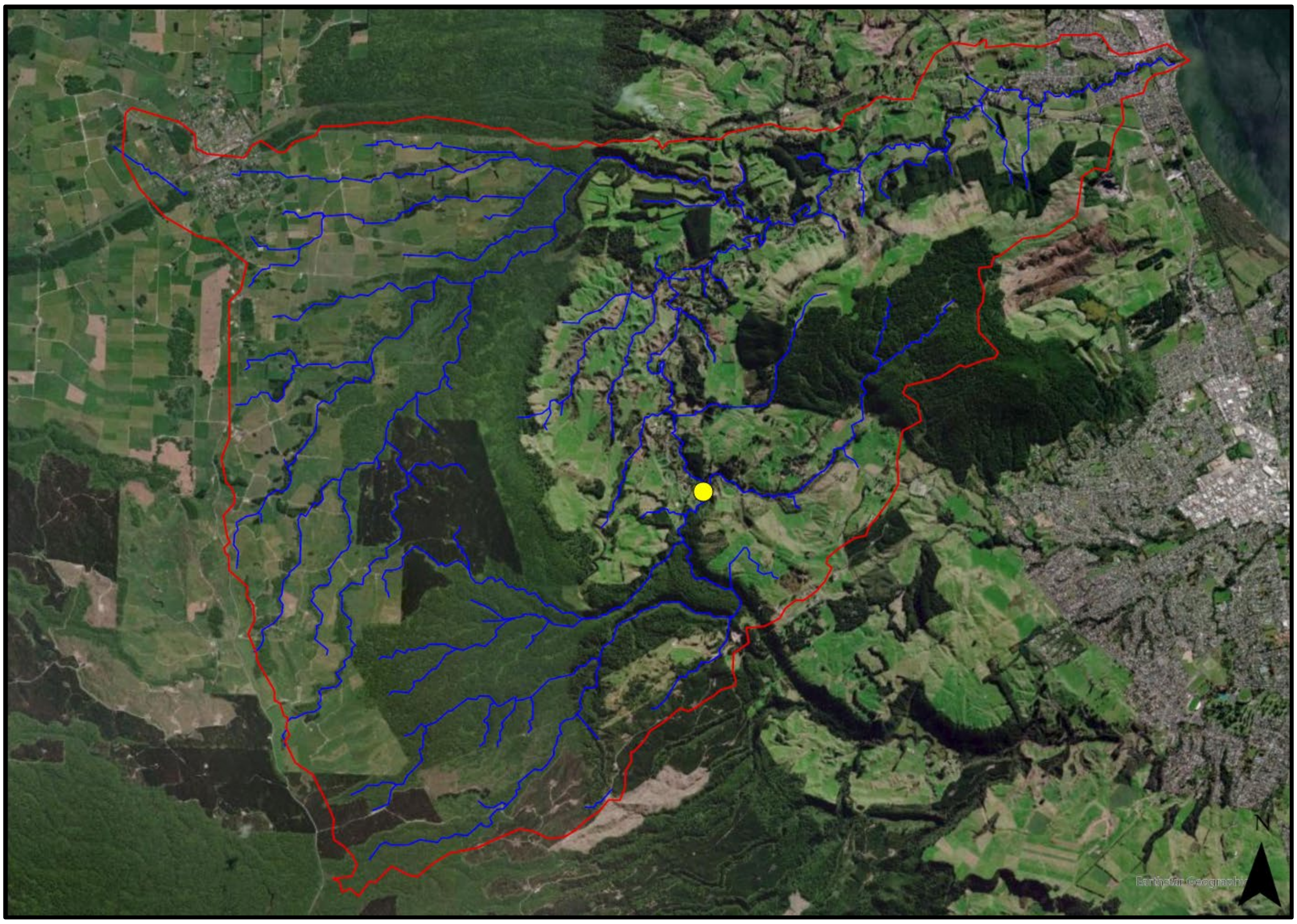

Figure A-2. Location of Ngongotahā at Paradise Valley in the Ngongotahā Catchment

Summary statistics

Table A-4.Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	15	0.003	0.006	0.008	0.00845	0.01085	0.0164
Conductivity (us/cm)	15	46.9	53.15	56.90	57.76	58.15	92
DO Sat (%)	15	92	93.25	94.6	94.47	95.9	97.6
DRP (g/m³)	15	0.0078	0.0105	0.012	0.01233	0.01275	0.021
E coli (g/m³)	15	35	104	260	563.5	575	3500
N total (g/m³)	15	0.74	0.781	0.835	0.829	0.8558	0.9449
Nitrate nitrate (as N) (g/m³)	14	0.6179	0.7225	0.7635	0.7572	0.8087	0.8580
O^2 (g/m³)	15	9.58	10.3	10.5	10.4	10.59	10.97
Total P (g/m³)	15	0.012	0.0163	0.018	0.01905	0.021	0.029
pH	15	6.93	7.03	7.08	7.062	7.11	7.14
Total suspended solids (g/m³)	15	1	1.764	2.4	3.876	3.562	12.6
Turbidity (NTU)	15	0.706	0.8545	1.49	1.6919	1.82	4.81
Water Temperature (°C)	15	8.4	10	10.3	10.92	11.65	14.8

State of the site

Microbiological guidelines assessment

Table A-5 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-5. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	660	1	1	3
Winter	10	170	6	3	1
All samples	15	260	7	4	4

Relph Rd Tributary Upstream Ngongotahā Confluence

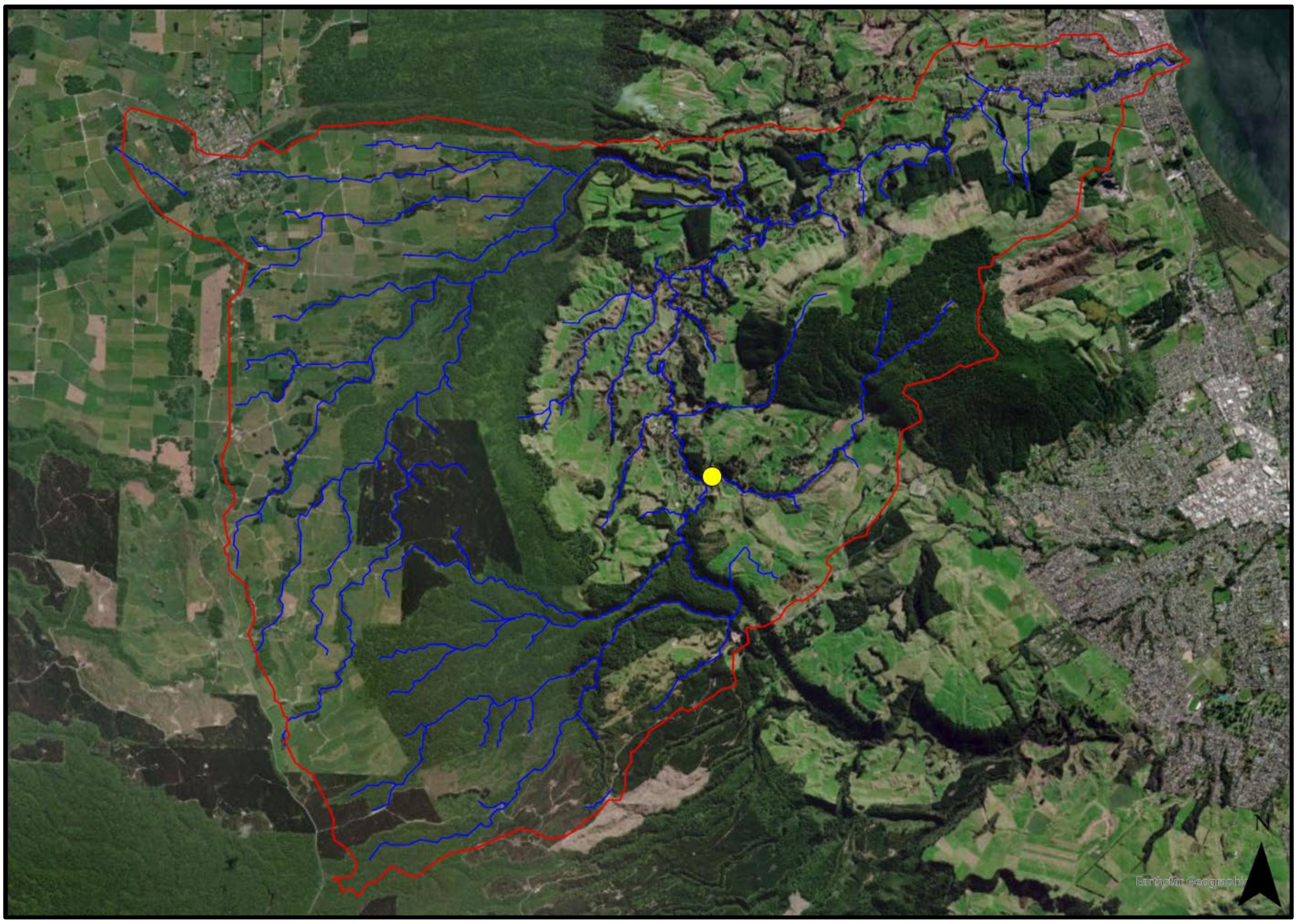

Figure A-3. Location of Relph Road Tributary upstream of the Ngongotahā Confluence in the Ngongotahā Catchment

Summary statistics

Table A-6. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	15	0.0015	0.0045	0.008	0.00827	0.0105	0.0181
Conductivity (us/cm)	15	54	66.65	68	68.76	71.55	78
DO Sat (%)	15	88.7	92.7	94.4	94.65	94.45	102
DRP (g/m^3)	14	0.002	0.0051	0.00905	0.00789	0.00968	0.013
E coli (g/m^3)	15	17	36	110	459.3	200	5200
N total (g/m^3)	14	0.5460	0.6593	0.7176	0.7106	0.7793	0.8377
Nitrate nitrate (as N) (g/m^3)	15	0.32	0.5465	0.6566	0.6255	0.6882	0.8970
O^2 (g/m^3)	15	9.02	9.525	10.08	10.042	10.55	10.95
Total P (g/m^3)	15	0.0135	0.01705	0.0199	0.02338	0.02375	0.063
pH	15	6.93	7.045	7.11	7.123	7.2	7.3
Total suspended solids (g/m^3)	15	1.125	1.757	3.9	7.599	5.563	63.667
Turbidity (NTU)	15	1.05	1.315	2.4	5.004	3.275	43.3
Water Temperature (^{o}C)	15	8	10.8	12.2	12.55	14	17.9

State of the site

Microbiological guidelines assessment

Table A-7 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-7. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	280	2	2	1
Winter	10	50	10	0	0
All samples	15	110	12	2	1

Ngongotahā at Paradise Valley Road

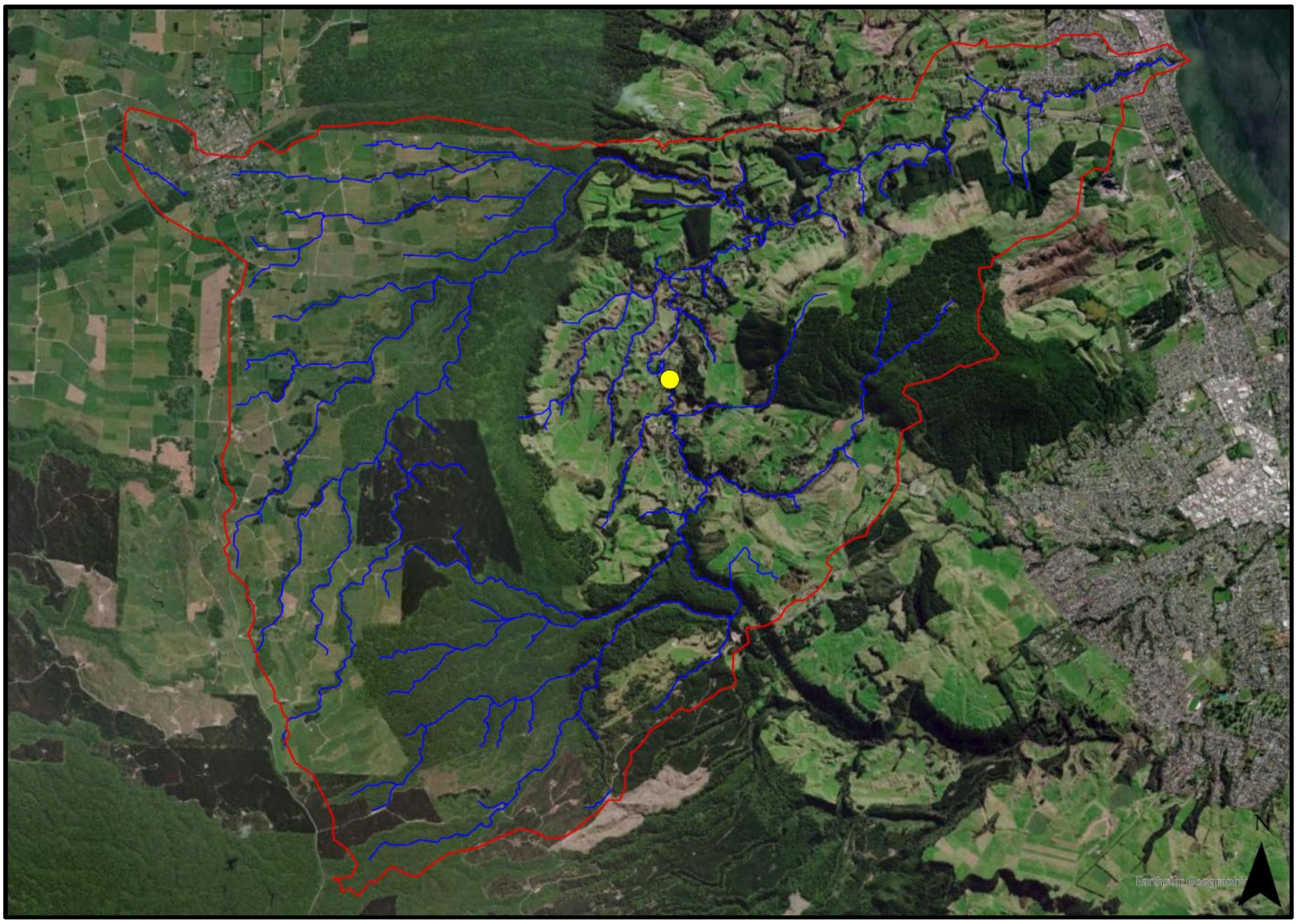

Figure A-4. Location of Ngongotahā at Paradise Valley Road in the Ngongotahā Catchment

Summary statistics

Table A-8. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	15	0.003	0.0115	0.014	0.01289	0.015	0.0188
Conductivity (us/cm)	15	48	56.7	60	59.13	61.25	70
DO Sat (%)	15	86.1	90.35	91.2	91.52	93.15	95
DRP (g/m³)	15	0.0059	0.007	0.008	0.00813	0.009	0.011
E coli (g/m³)	15	41	175	210	697.9	540	6000
N total (g/m³)	15	0.7694	0.8139	0.8452	0.8501	0.8842	0.96
Nitrate nitrate (as N) (g/m³)	14	0.6318	0.7325	0.7496	0.7578	0.7920	0.8730
O^2 (g/m³)	15	9.27	9.76	10.1	9.969	10.235	10.47
Total P (g/m³)	15	0.0124	0.01485	0.019	0.02125	0.024	0.053
pH	15	6.74	6.96	7.02	7.015	7.115	7.190
Total suspended solids (g/m³)	15	0.8889	3.7	4.9	7.2115	5.4778	23.8333
Turbidity (NTU)	15	0.928	1.42	2.25	3.186	2.99	11.9
Water Temperature (°C)	15	9	10.35	10.9	11.37	12	15.3

State of the site

Microbiological guidelines assessment

Table A-9 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-9. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	540	1	2	2
Winter	10	200	7	2	1
All samples	15	210	8	4	3

Ngongotahā Upstream Ngongotahā North Tributary Confluence

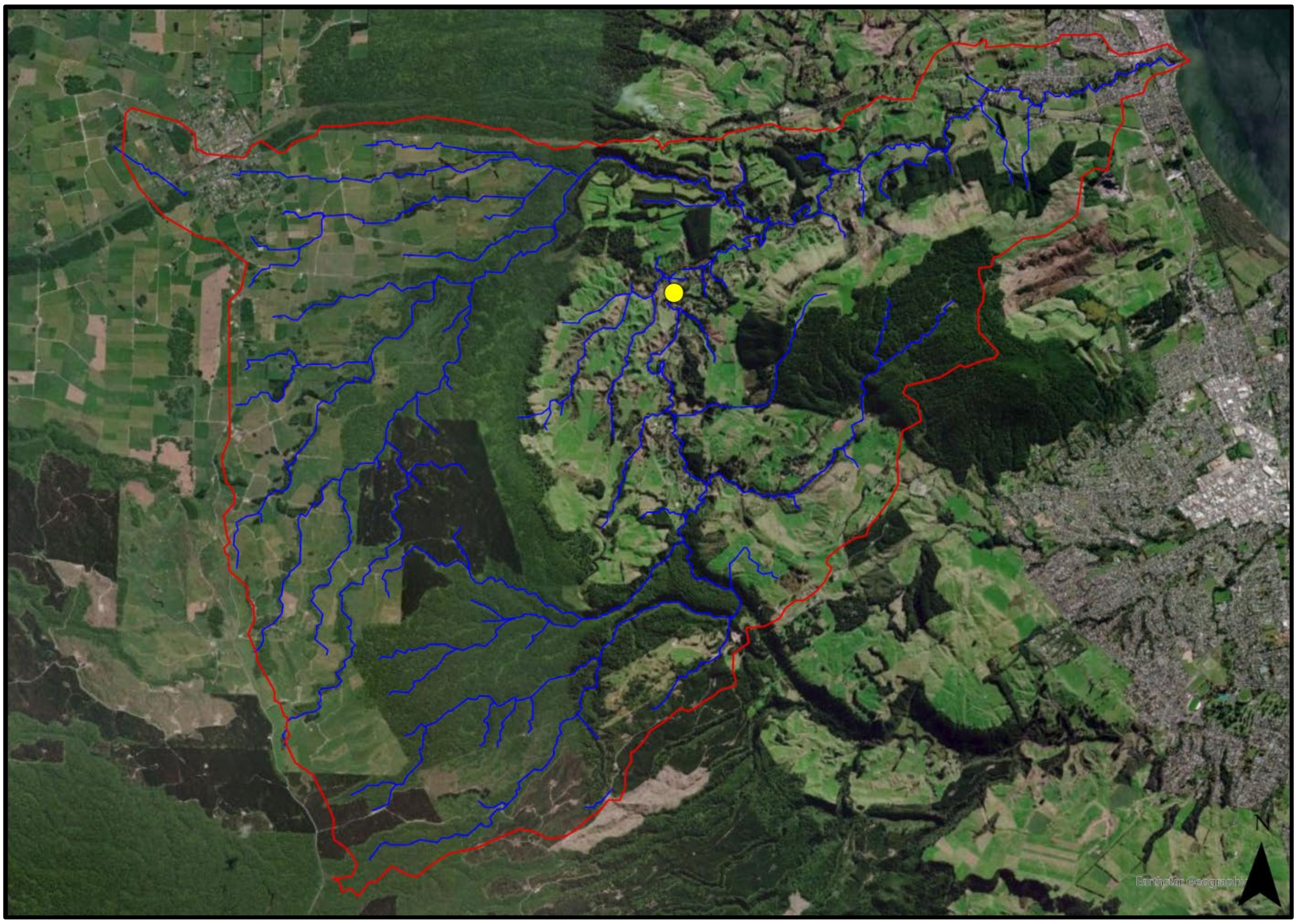

Figure A-5. Location of Ngongotahā upstream of the Ngongotahā North Tributary Confluence in the Ngongotahā Catchment

Summary statistics

Table A-10. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	12	0.002	0.009	0.0126	0.01202	0.01555	0.01870
Conductivity (us/cm)	12	56.2	58.73	60.55	60.76	62.25	69
DO Sat (%)	12	88.2	92.05	93.65	93.56	95.75	97.10
DRP (g/m^3)	12	0.0046	0.00573	0.00655	0.00668	0.00703	0.011
E coli (g/m^3)	12	48	130	225	278	412.5	600
N total (g/m^3)	12	0.7293	0.7835	0.8089	0.8096	0.8365	0.8867
Nitrate nitrate (as N) (g/m^3)	12	0.6188	0.6992	0.7260	0.7291	0.7546	0.8290
O_2 (g/m^3)	12	9.38	9.982	10.305	10.175	10.415	10.720
Total P (g/m^3)	12	0.0116	0.015	0.01985	0.01966	0.02205	0.0334
pH	12	7	7.1	7.180	7.176	7.250	7.32
Total suspended solids (g/m^3)	12	3.111	3.983	5.139	6.513	7.878	18.667
Turbidity (NTU)	12	1.05	1.923	2.57	3.194	3.455	10.2
Water Temperature (^{o}C)	12	8.7	10.18	10.7	11.41	11.78	16

State of the site

Microbiological guidelines assessment

Table A-11 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-11. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	3	580	0	1	2
Winter	9	160	7	2	0
All samples	12	225	7	3	2

Ngongotahā North Tributary Upstream North Confluence

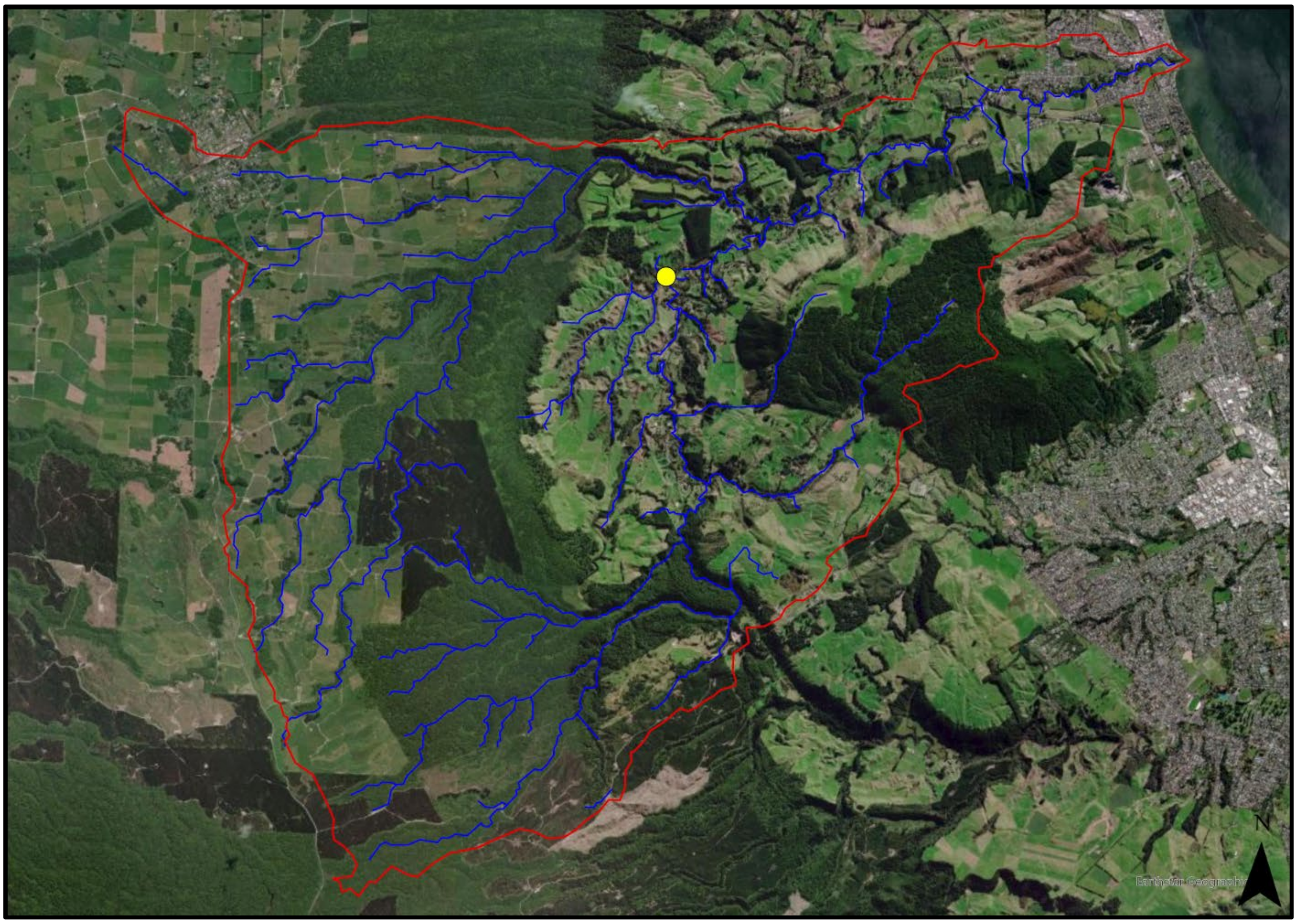

Figure A-6. Location of Ngongotahā North Tributary upstream of the North Confluence in the Ngongotahā Catchment

Summary statistics

Table A-12. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	12	0.001	0.01175	0.01695	0.01612	0.02065	0.031
Conductivity (us/cm)	12	52	55.27	58.85	59.19	62.05	74
DO Sat (%)	12	87.2	89.92	90.55	91.25	92.17	97
DRP (g/m^3)	12	0.0069	0.01008	0.014	0.01467	0.01610	0.027
E coli (g/m^3)	12	26	60.25	155	166.67	263.5	380
N total (g/m^3)	12	0.3906	0.4375	0.4691	0.4943	0.5333	0.6704
Nitrate nitrate (as N) (g/m^3)	12	0.2810	0.3204	0.3495	0.3542	0.3857	0.4487
O_2 (g/m^3)	12	9.19	9.598	9.88	9.885	10.19	10.61
Total P (g/m^3)	12	0.0285	0.03318	0.0375	0.04657	0.0532	0.088
pH	12	6.67	6.915	6.99	6.978	7.093	7.17
Total suspended solids (g/m^3)	12	1.444	3.188	4.00	9.803	8.145	51.2
Turbidity (NTU)	12	1.16	2.797	4.34	5.376	5.838	14.6
Water Temperature (°C)	12	8.4	10.65	11.1	11.62	12.57	15.2

State of the site

Microbiological guidelines assessment

Table A-13 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-13. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	3	270	0	3	0
Winter	9	150	8	1	0
All samples	12	155	8	4	0

Ngongotahā at Above Umurua Confluence

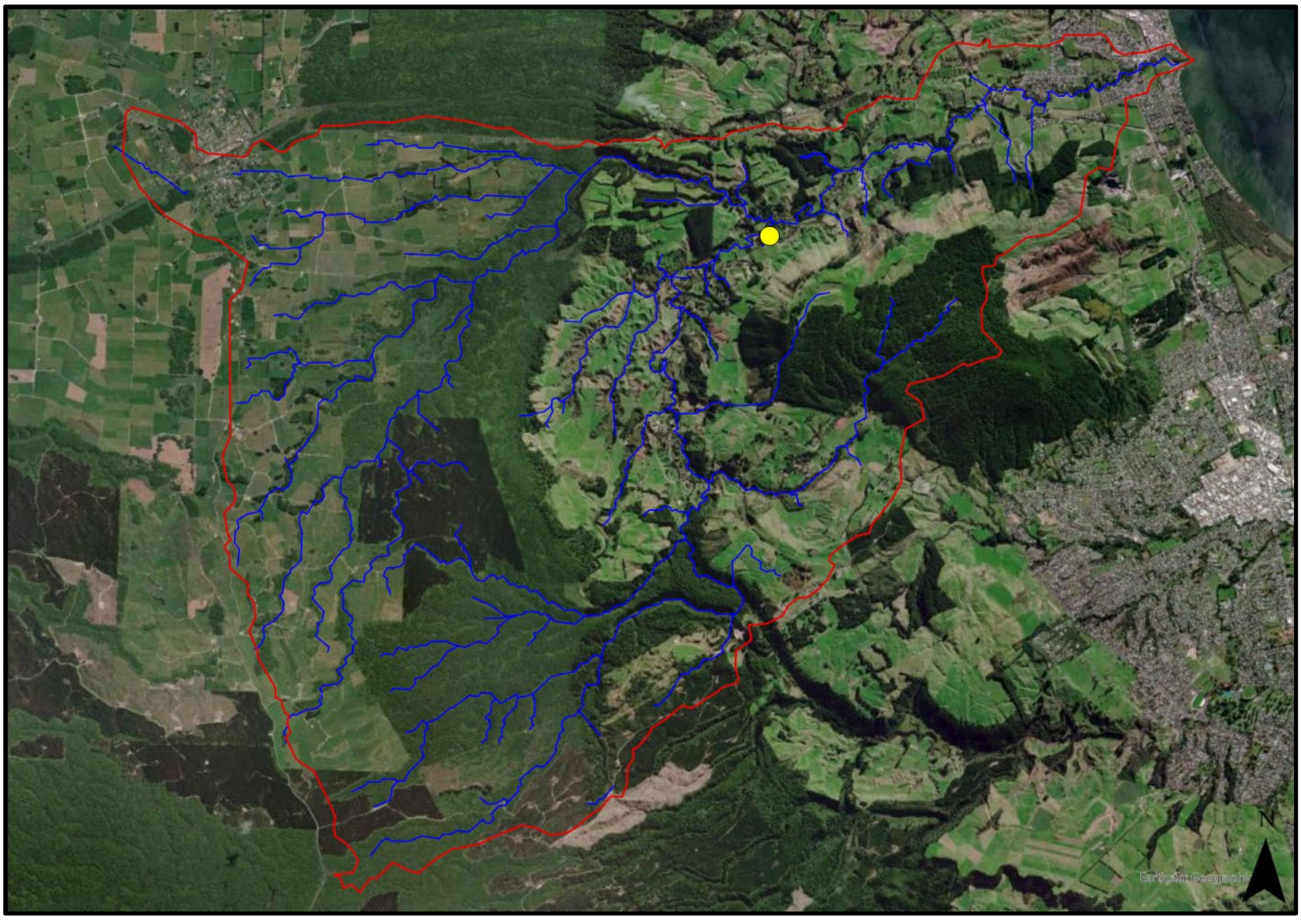

Figure A-7. Location of Ngongotahā at above Umurua Confluence in the Ngongotahā Catchment

Summary statistics

Table A-14. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	11	0.0002	0.0055	0.009	0.009055	0.01290	0.0184
Conductivity (us/cm)	11	59.4	61.5	63.8	63.65	65.1	69
DO Sat (%)	11	89.2	92	93	93.85	95	100
DRP (g/m³)	11	0.0188	0.02960	0.035	0.03266	0.03615	0.041
E coli (g/m³)	11	27	50.5	120	628.1	295	5300
N total (g/m³)	11	0.624	0.6527	0.667	0.679	0.6970	0.7529
Nitrate nitrate (as N) (g/m³)	11	0.496	0.5985	0.61	0.6113	0.629	0.708
O_2 (g/m³)	11	9.54	10.1	10.3	10.23	10.39	10.78
Total P (g/m³)	11	0.03920	0.04305	0.045	0.04765	0.053	0.057
pH	11	6.7	6.735	6.810	6.881	7.01	7.21
Total suspended solids (g/m³)	11	0.7778	3.0556	4.2	7.0222	5.55	28.2
Turbidity (NTU)	11	1.33	1.79	2.32	3.629	2.77	13.1
Water Temperature (°C)	11	9.2	10.75	11.2	11.23	11.4	13.3

State of the site

Microbiological guidelines assessment

Table A-15 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-15. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	3	440	0	2	1
Winter	8	90	7	1	0
All samples	11	120	7	3	1

Umurua at upstream Ngongotahā Confluence

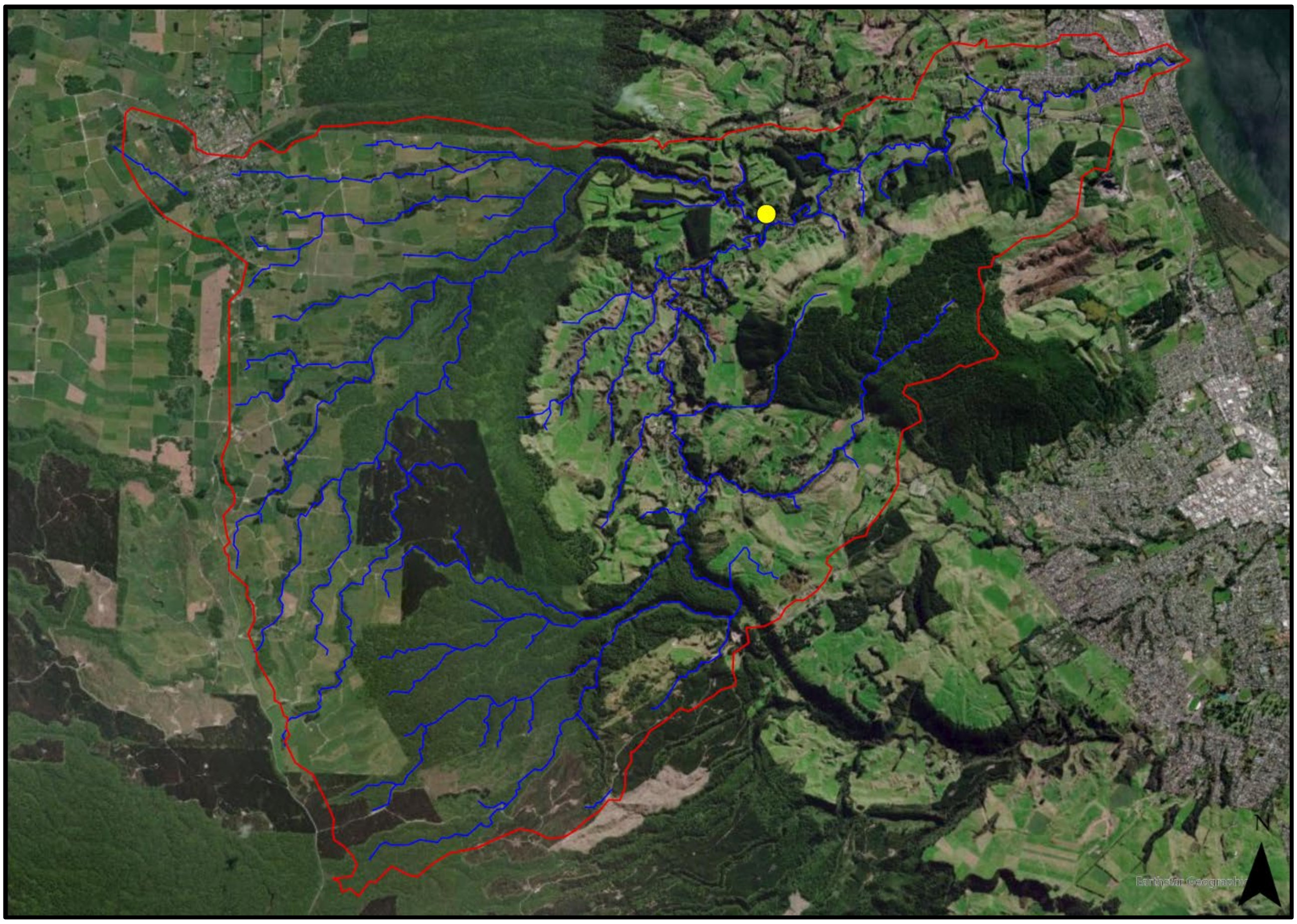

Figure A-8. Location of Umurua upstream of the Ngongotahā Confluence in the Ngongotahā Catchment

Summary statistics

Table A-16. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m3)	11	0.0014	0.0045	0.007	0.006136	0.008	0.0092
Conductivity (us/cm)	11	55.1	63.25	64	63.88	66.3	70.2
DO Sat (%)	11	92.3	96.3	100.5	99.58	101.5	107.2
DRP (g/m3)	11	0.013	0.01525	0.0209	0.02102	0.0255	0.032
E coli (g/m3)	11	7	37.5	120	266.7	275	1300
N total (g/m3)	11	0.982	1.021	1.033	1.063	1.121	1.149
Nitrate nitrate (as N) (g/m3)	11	0.842	0.9	0.937	0.9566	1.0088	1.0976
O2 (g/m3)	11	9.66	10.68	10.87	10.89	10.99	12.08
Total P (g/m3)	11	0.0213	0.0255	0.0307	0.03151	0.0375	0.042
pH	11	7.01	7.125	7.19	7.187	7.24	7.41
Total suspended solids (g/m3)	11	0.5556	1.0028	1.2	2.2706	3.4286	6.9
Turbidity (NTU)	11	0.715	0.9835	1.48	1.696	1.92	4.14
Water Temperature (oC)	11	9.10	10.00	10.5	11.05	11.75	15.40

State of the site

Microbiological guidelines assessment

Table A-17 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-17. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	3	240	2	0	1
Winter	8	50	6	1	1
All samples	11	120	8	1	2

Ngongotahā at SH5

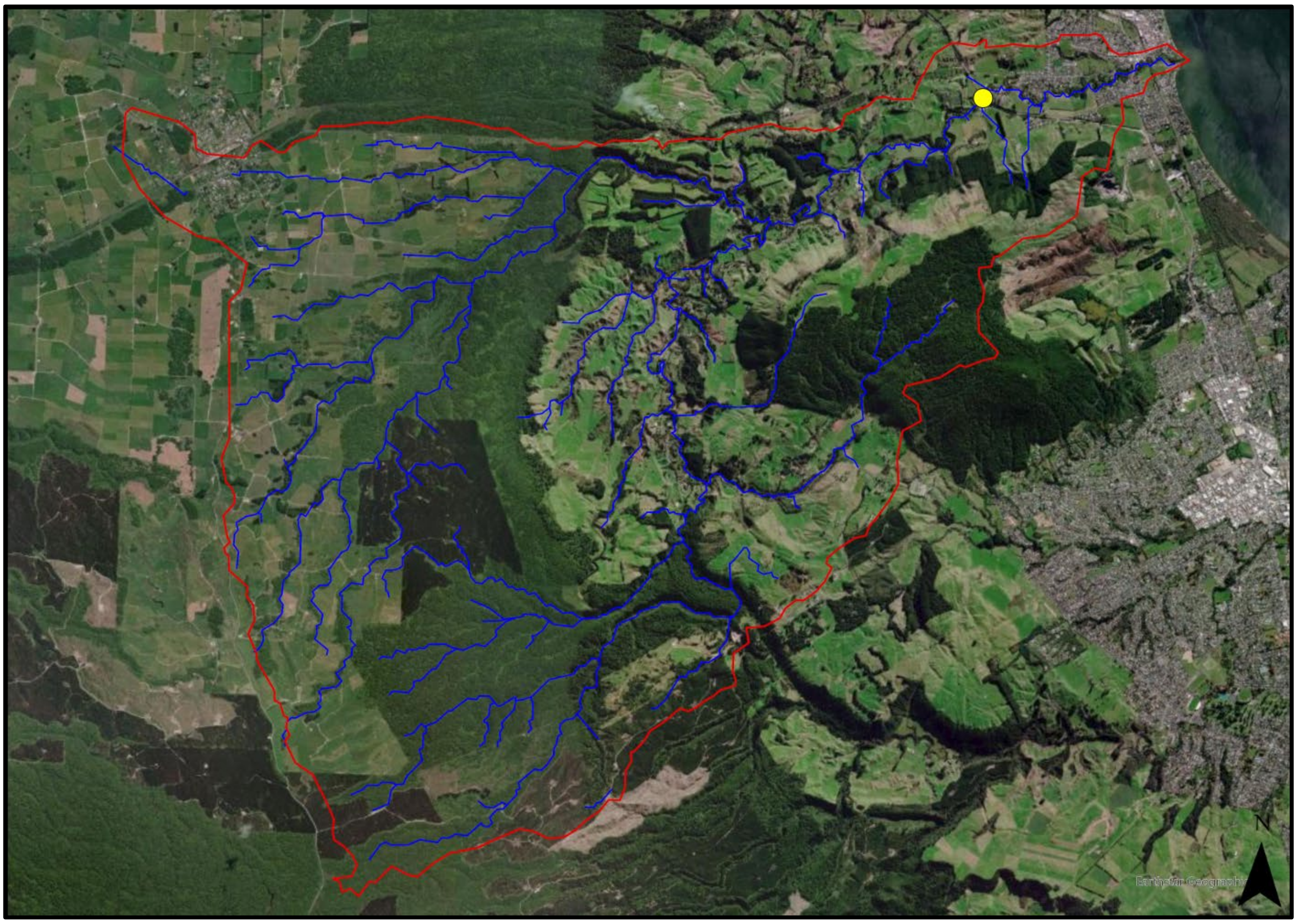

Figure A-9. Location of Ngongotahā at SH5 in the Ngongotahā Catchment

Summary statistics

Table A-18. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	15	0.0008	0.009	0.0108	0.0118	0.013	0.028
Conductivity (us/cm)	15	62	66	67.5	67.61	69.05	75
DO Sat (%)	15	89.5	93.25	96.9	96.77	97.9	109.50
DRP (g/m^3)	15	0.021	0.0264	0.0291	0.0291	0.032	0.0361
E coli (g/m^3)	15	19	76	250	339.8	405.0	1800
N total (g/m^3)	15	0.7130	0.7709	0.8290	0.8350	0.8875	1.0356
Nitrate nitrate (as N) (g/m^3)	15	0.6450	0.676	0.7130	0.7282	0.7785	0.875
O^2 (g/m^3)	15	9.25	10.01	10.23	10.33	10.43	12.48
Total P (g/m^3)	15	0.0364	0.04335	0.046	0.04999	0.0515	0.0894
pH	15	7.04	7.155	7.2	7.215	7.305	7.42
Total suspended solids (g/m^3)	15	0.4444	4.3056	6.6	10.8851	8.2857	59.40
Turbidity (NTU)	15	0.814	1.755	3.05	3.951	4.435	11.6
Water Temperature (^{o}C)	15	9.6	11.25	12.10	12.26	13.05	15.7

State of the site

Microbiological guidelines assessment

Table A-19 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-19. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	250	3	1	1
Winter	10	260	5	5	0
All samples	15	250	8	6	1

Ngongotahā at SH36

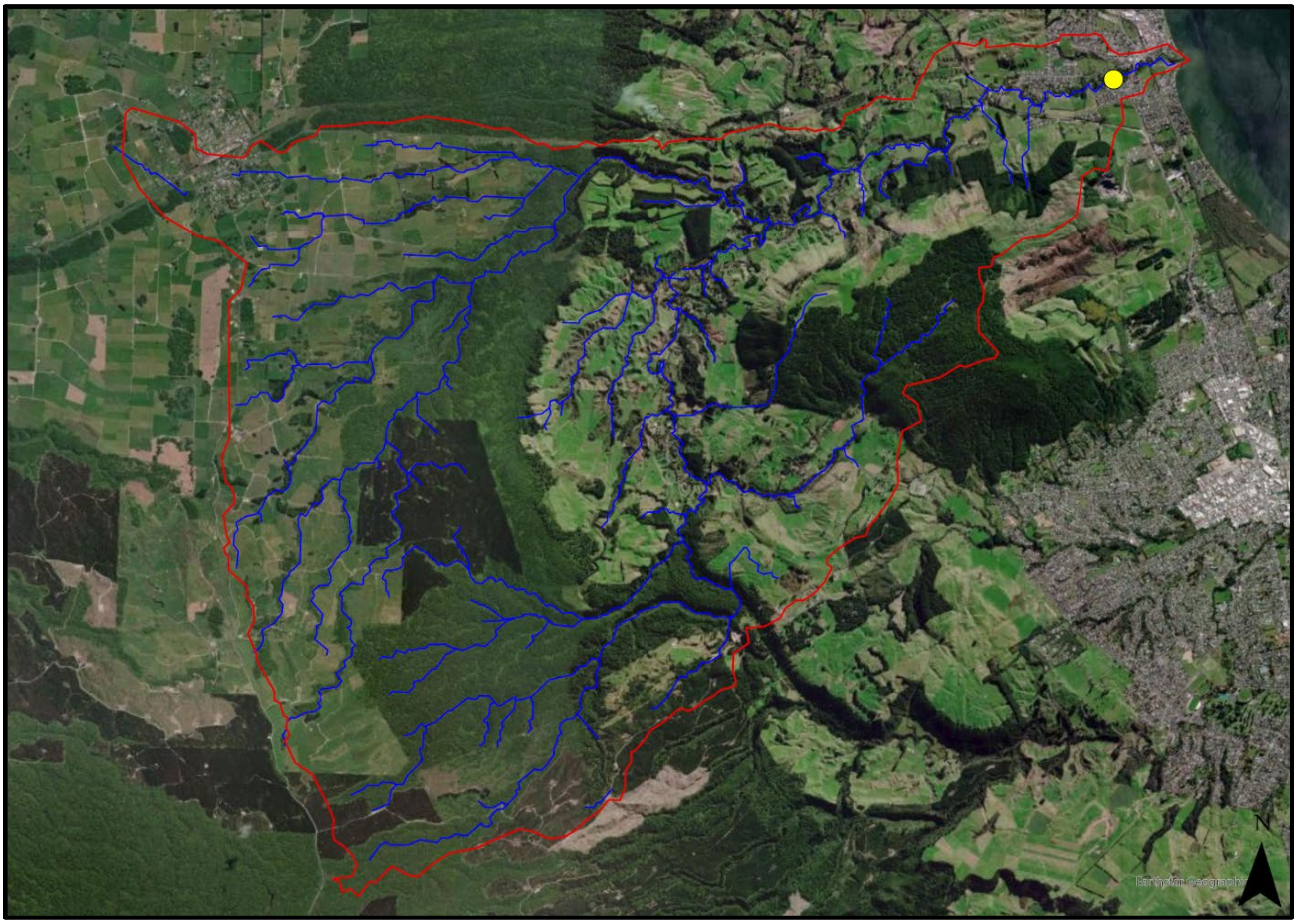

Figure A-10. Location of Ngongotahā at SH36 in the Ngongotahā Catchment

Summary statistics

Table A-20. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	14	0.0026	0.012	0.01425	0.01574	0.01865	0.0301
Conductivity (us/cm)	14	58.7	65	68.75	67.65	70.67	76
DO Sat (%)	13	90.7	91.7	93.3	94.02	96.9	98.3
DRP (g/m³)	14	0.01770	0.02005	0.024	0.02384	0.026	0.034
E coli (g/m³)	14	20	142.5	210	388.6	442.5	1600
N total (g/m³)	14	0.6915	0.7585	0.8240	0.8237	0.8428	1.119
Nitrate nitrate (as N) (g/m³)	14	0.562	0.68	0.7143	0.7147	0.7514	0.8150
O^2 (g/m³)	13	9.45	9.77	9.99	9.953	10.11	10.51
Total P (g/m³)	14	0.0336	0.04325	0.04580	0.04669	0.04875	0.0758
pH	14	6.88	7.11	7.145	7.133	7.215	7.31
Total suspended solids (g/m³)	14	1	4.55	5.816	7.857	9.114	28.444
Turbidity (NTU)	14	1.45	2.748	3.055	4.459	4.535	16.35
Water Temperature (°C)	13	11.1	11.5	12.4	12.77	13.5	15.5

State of the site

Microbiological guidelines assessment

Table A-21 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table A-21. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	210	3	1	1
Winter	9	150	6	1	2
All samples	14	210	9	2	3

Comparison plots

The figures below compare median values for eight different measurements collected at SH36 (the swimming site in the Ngongotaha catchment) against the distribution of data from all sites in the Bay of Plenty Region. The black dot represents the site's percentile score, with 0% equalling worst, and 100% equalling best. Each coloured segment represents 25% of the overall distribution. The segment colour scheme ranges from red (worst 25% of sites) to blue (best 25% of sites).

The Ngongotahā site at SH36 is in the worst 50% of sites in the Bay of Plenty for most parameters. It is within the worst 25% of sites for *E. coli*.

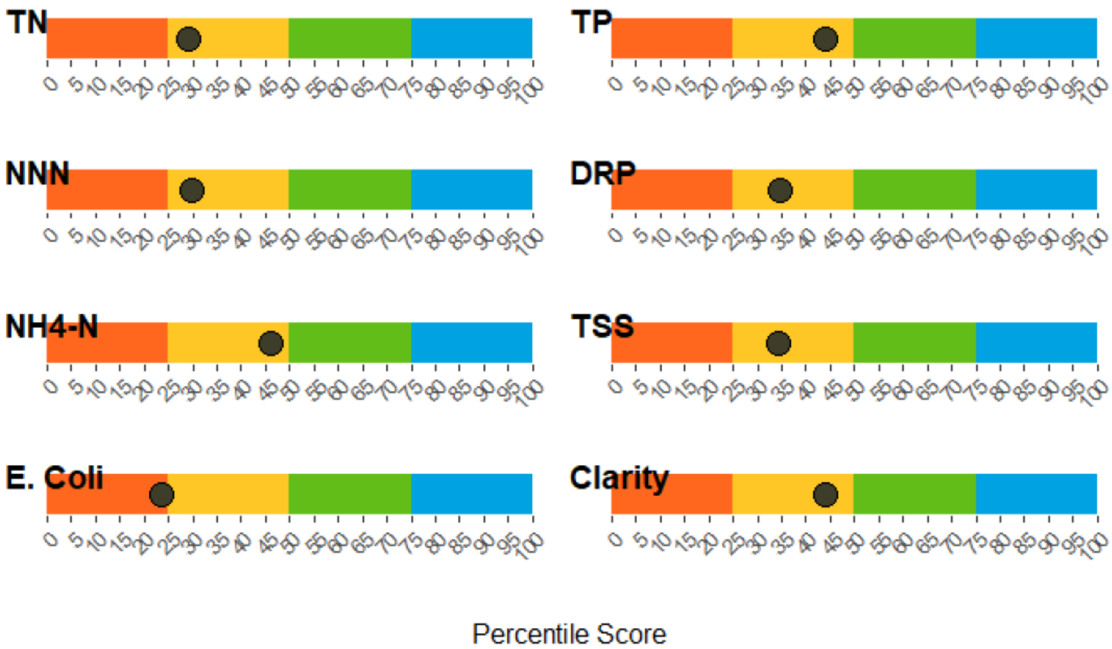

Figure A-11. Comparison of the monitoring site in Ngongotahā Stream at SH36 against other monitoring sites in the Bay of Plenty

4 Uretara, Katikati

4.1 Introduction (Kupu Whakataki)

The Henry Road Ford bathing site in the Uretara catchment is ranked as one of the highest risk bathing sites in the region. Results collated between 2012 and 2017 report a mean *E. coli* concentration of 478cfu/100mL, which sits between the Alert/Amber (260 cfu/100mL) and Action/Red (550 cfu/100mL) thresholds set in the Microbiological Water Quality Guidelines. Over this period, 10% of samples had concentrations in excess of the Action/Red threshold, which was exceeded by only two other sites: Ngongotahā at Railway Bridge (18%) and Kaiate at Kaiate Falls Rd (24%).

Assessment of *E. coli* levels at the Henry Road Ford site against the swimmability/human health attribute band in Appendix 2 of the NPSFM suggests that 20-30% of the time, the estimated risk of Campylobacter infection is greater than 5%. The predicted average infection risk is greater than 3%. Therefore, this site is currently deemed unsuitable for recreational contact.

4.2 Purpose (Take)

The Henry Road Ford bathing site in the Uretara catchment is ranked as one of the highest risk bathing sites in the region, according to 2016/2017 Recreational Waters Surveillance Report (Scholes 2018). Results collated between 2012 and 2017 report a *mean E.* coli concentration of 478cfu/100mL, which sits between the Alert/Amber (260 cfu/100mL) and Action/Red (550 cfu/100mL) thresholds set in the Microbiological Water Quality Guidelines (MWQG) (MfE, 2003).

In response to the Recreational Waters Surveillance Report, an investigation was designed to gather a more in-depth understanding of the *E. coli* issue within the catchment and direct the focus of mitigating actions. The objectives of this investigation were to determine; where the *E. coli* loads might be coming from within the catchment, if any patterns could be seen in regard to weather and flow patterns, and identify the contributing animal sources (Human, Ruminant, Canine, and Avian) via faecal source tracking (FST).

4.3 Catchment Description (Whakaaturanga o te Takiwā)

The Uretara Catchment is 4100 hectares and includes the township of Katikati. The total catchment is comprised of approximately 1619 ha (39%) indigenous forest, 1528 ha (37%) pasture, 697 ha (17%) horticulture with the remaining land being 65 ha of exotic forest (2%) and 187 ha of urban (4%) areas (BOPRC, 2020).

The Uretara Stream is the principal waterway which is fed by three distinct tributary watersheds; the Uretara and Wharawhara tributary watersheds flow across the Uretara Catchment, and the McKinney Tributary joins the network downstream of the Henry Road Ford. As the McKinney joins the network after the swimming site, it is not part of the present assessment. The tributaries flow to the Uretara Estuary.

The main Uretara watershed is primarily comprised of indigenous forest in the Kaimai Forest Park with a narrow band of pastoral farming and horticulture either side of the river from where it leaves the Forest Park.

The Boyd/Quarry watershed is primarily a modified landscape with only a small proportion of indigenous forest and three tributaries (Wharawhara, Quarry and Boyd streams) each draining a portion of the area. The land use is mainly pastoral dry stock grazing in the steeper landscape towards the Kaimai Forest Park and becomes dominated by horticulture in the lower terraces and rolling landscape. Until early 2018 a dairy farm operated in the lower part of this watershed though this has now converted to dry stock farming with additional conversion to avocados being planned on this property.

4.4 Key Issues (Ngā Kaupapa Mātuatua)

The *E. coli* levels and subsequent swimmability in the Uretara catchment was identified as the primary water quality issue for the catchment. Reducing *E. coli* levels for swimmability/human health was identified as the primary target of mitigation and management.

4.5 Methodology (Huarahi) / Monitoring Summary

Sampling commenced at 14 sites in the Uretara catchment on January 2018, and was completed in April 2022. The locations of the sampling sites are shown in Figure 4-1 and the corresponding names, identification numbers, and co-ordinates are listed in Table 4-1. The sites have been grouped into ‘branches’ of the stream network, and ordered by upstream to downstream sites within the branches. This ordering is reflected in all figures.

Table 4-1 Location, identification and co-ordinates of each site in the Uretara catchment

Location Name	ID	Latitude	Longitude
Boyd Tributary			
Boyd at Amrein's	BQ423916	-37.55945969	175.8783
Boyd Tributary at Busby Road	BQ428930	-37.55818939	175.8788
Boyd 500m u/s Quarry confluence	BQ598917	-37.55890706	175.8981
Boyd u/s Uretara confluence	BQ653907	-37.55968857	175.9043
Quarry Creek			
Peach's Creek at U/S Quarry Creek Confluence	BQ316859	-37.56491089	175.8664
Quarry Creek at U/S Peach's Creek Confluence	BQ317857	-37.56507874	175.8665
Quarry u/s Haworth's confluence	BQ405872	-37.56346893	175.8764
Haworth's u/s Quarry confluence	BQ407870	-37.56368527	175.8766
Quarry u/s Boyd confluence	BQ623904	-37.56003952	175.9009
Uretara Stream			
Uretara d/s of Filter Station	BQ297798	-37.57046127	175.8645
Wharawhara Rd Tributary u/s Uretara Confluence	BQ658886	-37.56151224	175.905
Uretara u/s Wharawhara Rd Tributary	BQ662885	-37.56161051	175.9054
Uretara at Above Boyd Tributary	BQ663900	-37.56029892	175.9054
Uretara at Henry Rd Ford	BQ723939	-37.55659103	175.9121

Table 4-2 Landscape descriptions at the Uretara monitoring sites, grouped into stream network 'branches'

Location Name	Land type[6]	Land Cover[7]
Boyd Tributary		
Boyd at Amrein's	Rolling to strongly rolling slopes	High-producing exotic grassland and some exotic forestry
Boyd Tributary at Busby Road	Strongly rolling to moderately steep hills	High-producing exotic grassland exotic grassland and some exotic forestry
Boyd 500m u/s Quarry confluence	Strongly rolling to moderately steep hills	High-producing exotic grassland
Boyd u/s Uretara confluence	Strongly rolling to moderately steep hills	Deciduous hardwoods / indigenous forest
Quarry Creek		
Peach's Creek at u/s Quarry Creek Confluence	Strongly rolling to moderately steep hills	High-producing exotic grassland exotic grassland and some exotic forestry
Quarry Creek at u/s Peach's Creek Confluence	Strongly rolling to moderately steep hills	High-producing exotic grassland exotic grassland and some exotic forestry
Quarry u/s Haworth's confluence	Strongly rolling to moderately steep hills	Orchard, Vineyard or Other Perennial Crop
Haworth's u/s Quarry confluence	Strongly rolling to moderately steep hills	Orchard, Vineyard or Other Perennial Crop
Quarry u/s Boyd confluence	Strongly rolling to moderately steep hills	Deciduous hardwoods
Uretara Stream		
Uretara d/s of Filter Station	Strongly rolling to moderately steep hills	Indigenous forest
Wharawhara Rd Tributary u/s Uretara Confluence	Flat to gently undulating	Orchard, Vineyard or Other Perennial Crop
Uretara u/s Wharawhara Rd Tributary	Flat to gently undulating	Orchard, Vineyard or Other Perennial Crop
Uretara at Above Boyd Tributary	Flat to gently undulating	High-producing exotic grassland exotic grassland
Uretara at Henry Rd Ford	Flat to gently undulating	High-producing exotic grassland

[6] NZLRI Land Use Capability 2021 – LRIS Portal, 2021. Retrieved from https://lris.scinfo.org.nz/search/?q=land+use. Accessed on 8 November 2022.

[7] LCDB v5.0 – Land Cover Database version 5.0, Mainland, New Zealand – LRIS Portal, 2020. Retrieved from https://lris.scinfo.org.nz/data/. Accessed on 8 November 2022.

4.5.1 Flow Gauging

Continuous flow measurements (5-minute intervals) were collected at Tuapiro at Farm Bridge until June 2020. Four monitoring sites that were not continuously monitored were selected to create synthetic flow equations based on the measurements from Tuapiro Farm Bridge. They were selected as they represented the four main branches/contributions into the Uretara Stream, and also the most downstream site (Henry Road Ford). The discrete grab sampling that occurred at these monitoring sites four times over a year, targeted the four seasons. These grab samples were then plotted against the continuous flow measurements to create the synthetic flow equation.

The relationship equations for specific monitoring sites are listed in Table 4-3.

Table 4-3. Flow data used in loading calculations. Synthetic data = based on relationships with Tuapiro at Farm Bridge flow (equations provided). Actual = measured flow on the day of sampling.

Site Name	Synthetic Flow / Actual Flow	Relationship Equation
Boyd 500m u/s Boyd East (Quarry) confluence	Synthetic flow	y = 0.0715x + 0.0066
Quarry u/s Boyd confluence	Synthetic flow	y = 0.035x + 0.0092
Uretara u/s Wharawhara Rd Tributary	Synthetic flow	y = 0.9129x – 0.0241
Uretara at Henry Rd Ford	Actual flow	NA

4.5.2 FST

E. coli results greater than 550 cfu/100 ml were stored for FST. Samples were analysed to identify the primary sources of faecal contamination.

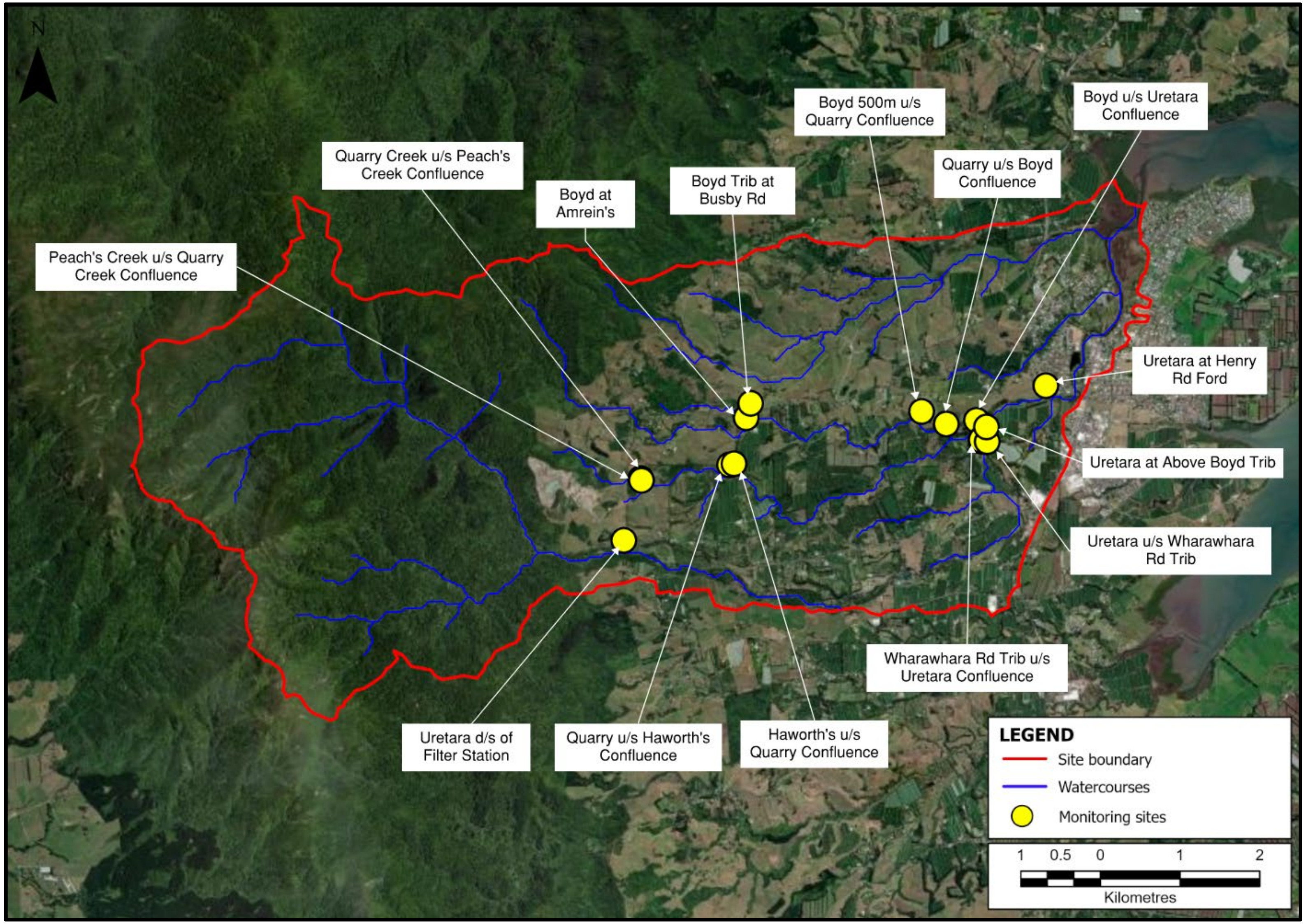

Figure 4-1. The Uretara Catchment (red polygon), stream network (blue polylines), and monitoring stations (yellow points), west of Katikati, New Zealand (Source: ArcGIS).

4.6 Results (Ngā Otinga)

The following graphs and discussion relate to results collected between 2018 and 2022. Rainfall and flow data is presented in Table 4-4 and Figure 4-2, to provide information on environmental conditions at the site during each sampling event. The boxplots present the results by site for conductivity, DO, pH, turbidity and water temperature (Figure 4-3 to Figure 4-7). These parameters are provided to give additional context on each site, which can be combined with the water quality investigation. Sites are ordered approximately from upstream to downstream. However, the monitoring stations are established at tributaries and confluences throughout the catchment, and therefore is not entirely linear.

E. coli concentration and load were also assessed via boxplot. According to a comparison plot of water quality data from the swimming site at Henry Road Ford versus the wider Bay of Plenty, water quality for all other parameters (DRP, Total-P, NNN, ammoniacal-N, and Total-N) are within the best 50% of sites. Therefore, the assessment will focus on the parameter of concern – *E. coli*.

4.6.1 Rainfall and Flow

Daily and hourly rainfall was recorded at a monitoring station located at Tuapiro at Farm Bridge, approximately 4.1 km north, outside of the Uretara catchment.

Summary of daily rainfall and flow data per month in the Uretara catchment (Rainfall 95th Percentile = 23 mm/day, Flow 95th Percentile = 3.32 m^3/sec). The overall flow and rainfall between 2018 and 2021 is shown in Figure 4-2. The intensive sampling during 2018 did capture a greater variety of environmental conditions. and there was at least one rain day per month in 2018 that exceeded the 95th percentile threshold, apart from in September and October. Flow events greater than the 95th percentile also occurred in seven of the 12 months in 2018. Flow events did not occur as consistently in the following years.

There were 711 days from 2018 to 2022 that exceeded the 95th percentile for rainfall. No sample event coincided with periods when rainfall was greater than the 95th percentile. Three sample events occurred when the 7-day rainfall total exceeded 150 mm (9 January 2018, 13 February 2018, and 17 February 2021). There were 49 days where flow exceeded the 95th percentile. One sample event occurred during a flow event that exceeded the 95th percentile (4.58 m^3/sec on 13 February 2018).

Table 4-4. Rainfall and flow data for the Uretara catchment from January 2018 to December 2020 (Rainfall 95th percentile = 23 mm/day, Flow 95th Percentile = 3.32 m^3/sec).

Year	Month & Year	Number of rain days	Number of rain days > 95th Percentile	Total monthly precipitation (mm)	Number of days flow > 95th Percentile
2018	January	16	4	257.1	1
	February	18	4	275.9	2
	March	16	2	125.9	0
	April	15	3	322.9	1
	May	17	1	139.6	0
	June	21	1	327.3	1
	July	19	3	184.9	3
	August	20	3	224.8	2
	September	13	0	67.0	0
	October	14	0	62.7	0
	November	19	2	212.3	0
	December	16	5	374.2	6

Year	Month & Year	Number of rain days	Number of rain days > 95th Percentile	Total monthly precipitation (mm)	Number of days flow > 95th Percentile
2019	January	5	0	9.7	0
	February	7	0	40.8	0
	March	10	0	55.4	0
	April	10	1	57.8	0
	May	15	0	57.1	0
	June	15	0	87.1	0
	July	21	2	260.3	0
	August	23	1	172.3	0
	September	17	5	232.1	0
	October	14	1	186.6	0
	November	6	0	35.6	0
	December	13	2	112.4	0
2020	January	4	0	18.0	1
	February	5	0	15.5	0
	March	9	0	37.5	3
	April	11	0	33	2
	May	17	1	110.5	0
	June	20	5	347.4	0
	July	17	4	237.4	0
	August	19	2	177.4	0
	September	15	0	64.9	0
	October	14	0	44.2	0
	November	17	3	235.8	1
	December	5	0	29.9	5
2021	January	9	0	32.3	0
	February	9	1	254.6	2
	March	14	1	101.9	0
	April	15	1	90.0	0
	May	17	1	117.5	0
	June	23	2	323.3	4
	July	18	1	145.4	1
	August	18	0	100.6	0
	September	20	3	196.4	2
	October	19	1	225.3	2
	November	16	0	97.0	0
	December	14	3	135.9	1

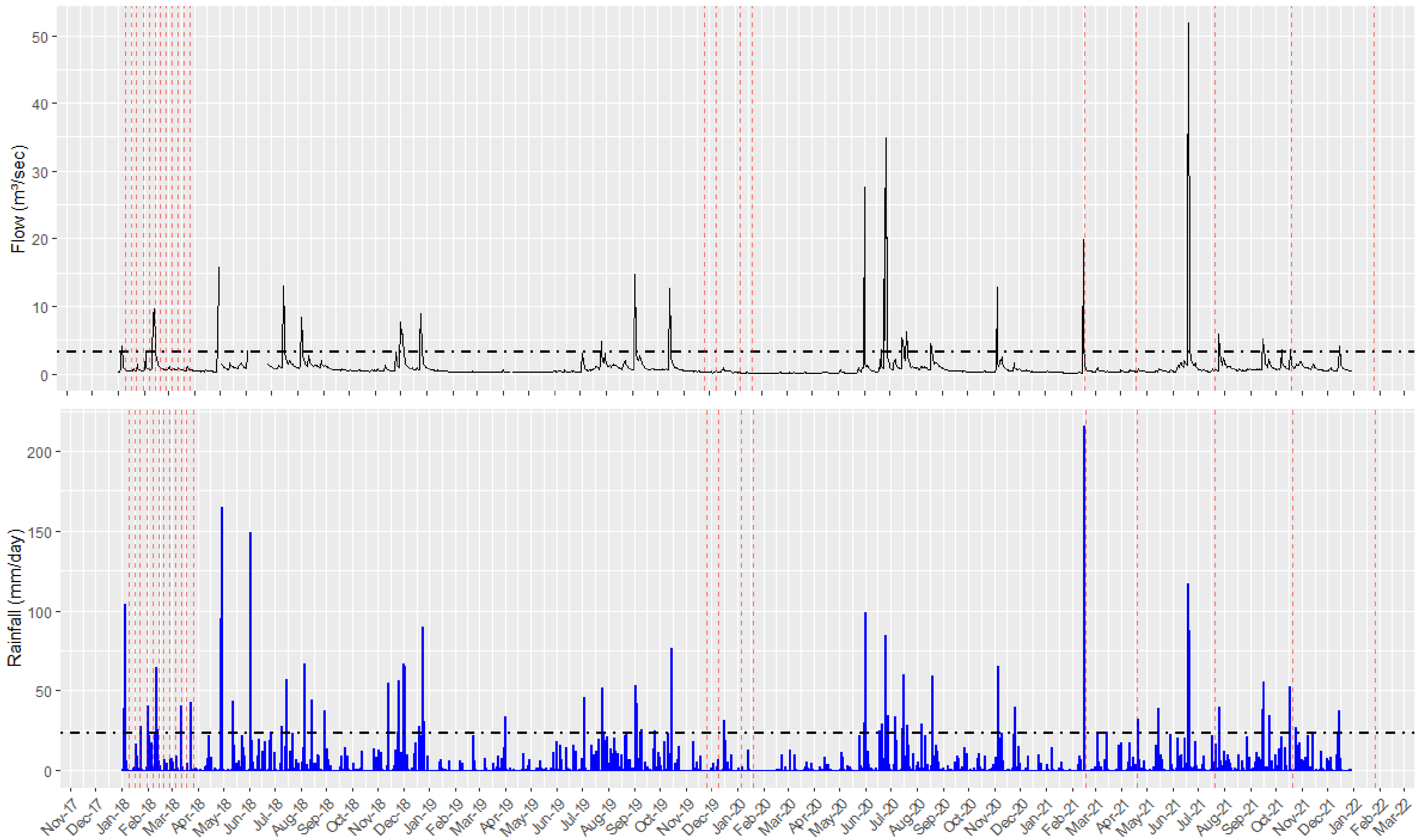

Figure 4-2. Daily flow (m3/sec) and rainfall (mm/day) in the Uretara catchment. The dashed lines represent the 95th percentile for each parameter (Rainfall 95th percentile = 23 mm/day, Flow 95th Percentile = 3.32 m^3/sec). Vertical red dashed lines indicate days in which sampling occurred.

4.6.2 Conductivity

The conductivity measurements collected from the sites were generally below the relevant DGV between 2018 and 2022, across all sites. There was little variation within and between sites. The median conductivity measured at 'Peach's Creek at u/s Quarry Creek confluence' and 'Wharawhara Road Tributary u/s Uretara confluence' were elevated compared to the other sites, but were still below the relevant DGV.

One measurement (188.5 us/cm, 'Uretara d/s of Filter Station', 17 February 2021) exceeded the DGV for CWH country by 50%. This was collected from one of the most upstream sample locations. This conductivity measurement coincided with an elevated *E. coli* measurement compared to the site median and occurred on the day of a large rainfall event (216 mm, 15 February 2021).

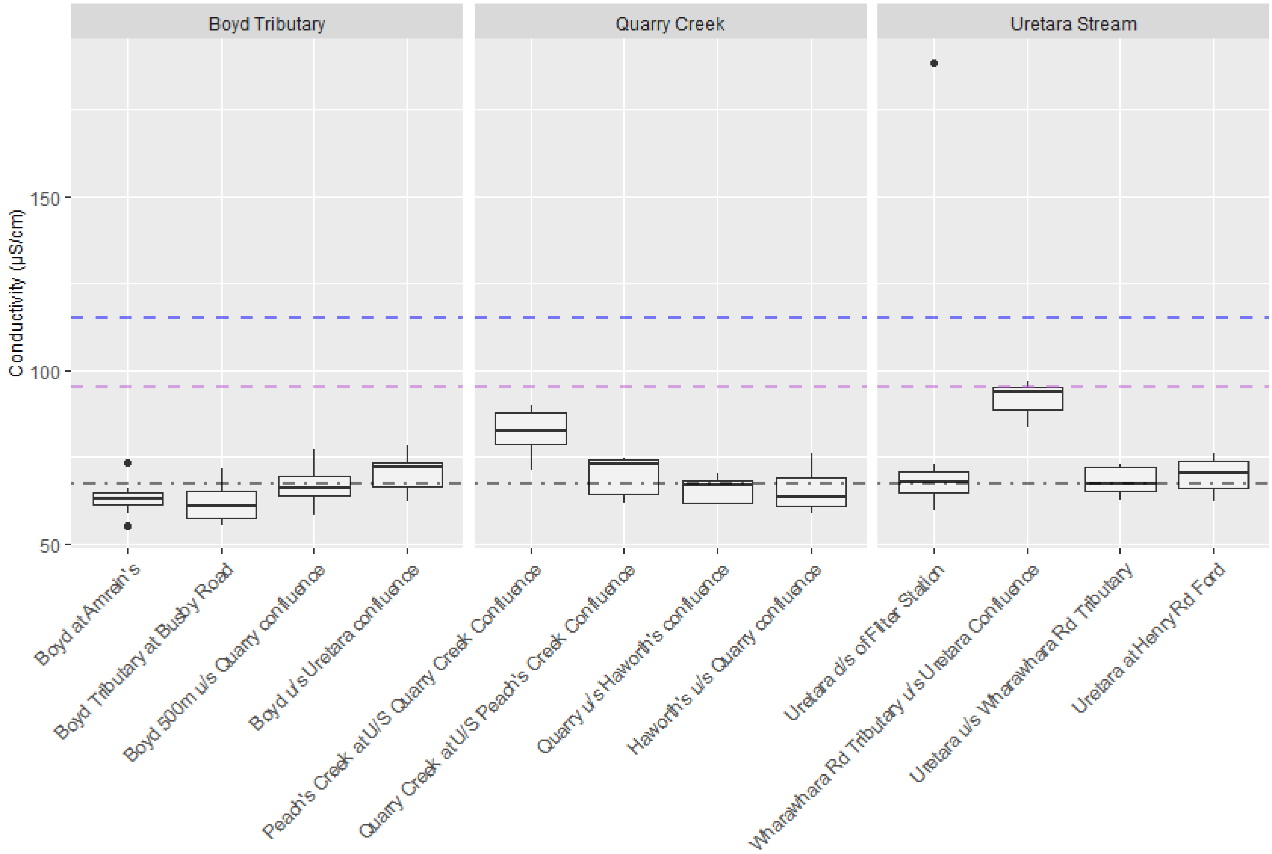

Figure 4-3. Conductivity (us/cm) at Uretara monitoring sites between 2018 and 2022. Comparative conductivity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

4.6.3 Dissolved Oxygen

The DO saturation (%) measurements taken from sites in the Uretara catchment range from 60.3% ('Wharawhara Road Tributary u/s Uretara Confluence') to 129% (Uretara at above Boyd Tributary). Generally, the Wharawhara Road tributary u/s Uretara confluence had the lowest median dissolved oxygen (%), and the median was below both ANZG DVGs for warm, wet low elevations. This monitoring location and the Haworth's u/s/ Quarry confluence had the greatest variation throughout the sample period. The median DO % at Haworths u/s Quarry confluence did not meet the CWH but did meet the DGV for waterways at WWL elevation.

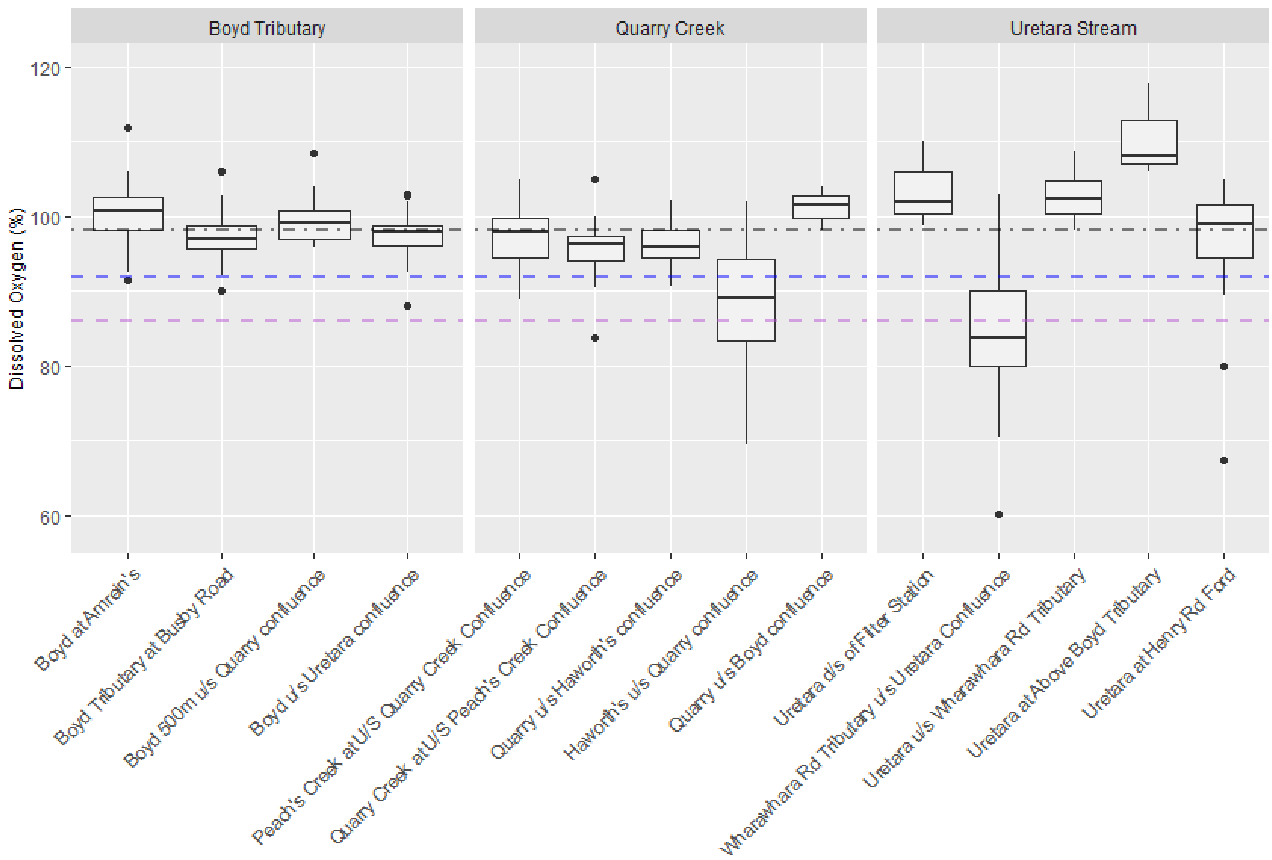

Figure 4-4. Dissolved oxygen saturation (%) at Uretara monitoring sites between 2018 and 2022. Comparative dissolved oxygen values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

4.6.4 Water Temperature

Water temperature varied between 10.4°C and 22.4°C, and generally showed similar variability across all sites. The water temperature readings from 'Uretara at Above Boyd Tributary' – which is one of the sites closest to the catchment outlet - showed the least variation in temperature across sample events, and had a higher minimum temperature than the other sites (17.1°C).

The Summer Cox-Rutherford index is used by BOPRC to assess median temperature in upland and lowland waterways. The medians for each location fall within the 'A' band for water temperature in lowland and upland areas (<18°C and <19°C, respectively).

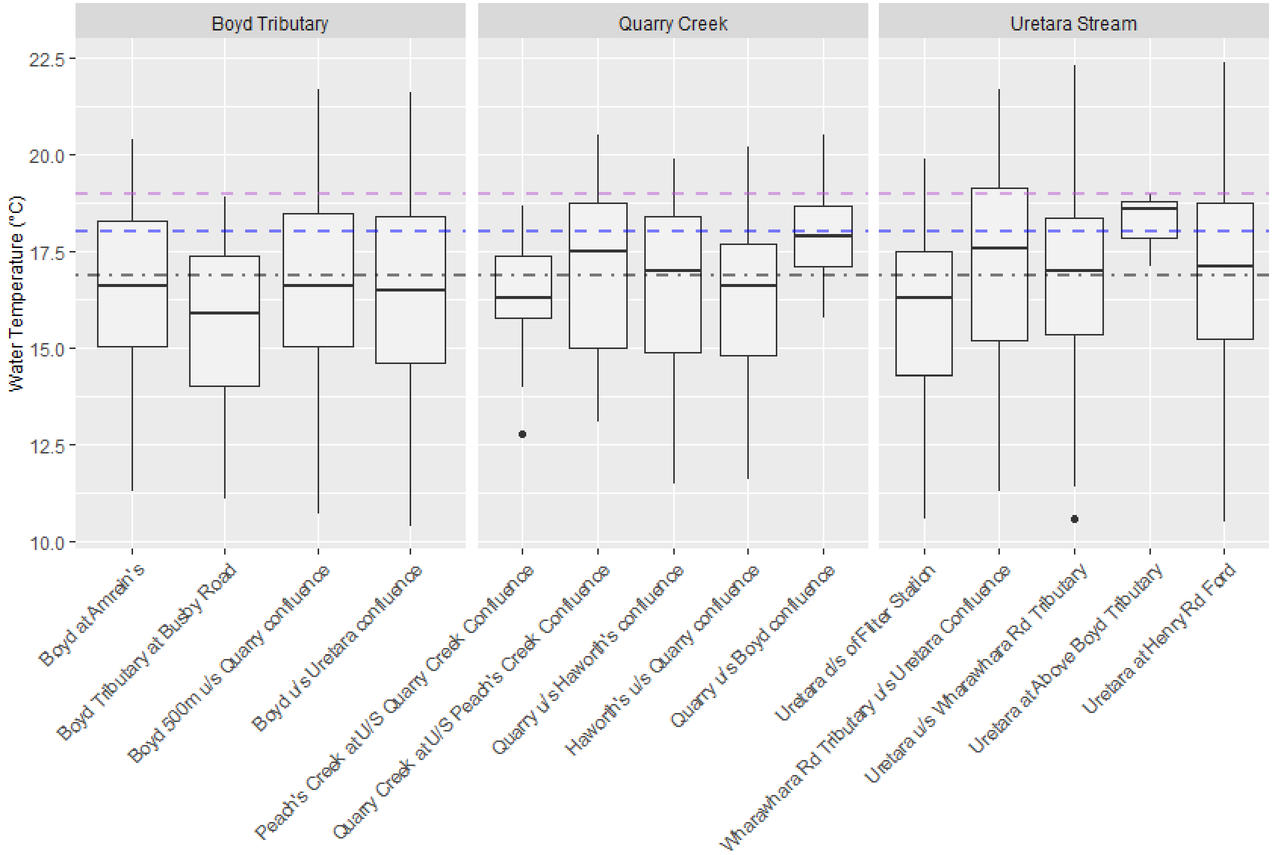

Figure 4-5. Water temperature (°C) at monitoring sites between 2018 and 2022. Comparative water temperature values shown are the catchment median (grey dashed line), and the Summer Cox-Rutherford index 'A' band temperature for lowland (blue) and upland (pink) waterways.

4.6.5 pH

Generally, the monitored sites were more acidic than the relevant DGV (pH 7.2-7.3). Recorded values ranged from a minimum of pH 6.2 and a maximum of pH 7.8. The median pH for the site at ‘Uretara d/s of Filter Station’ was more basic than the DGV. This is the most upgradient monitoring site.

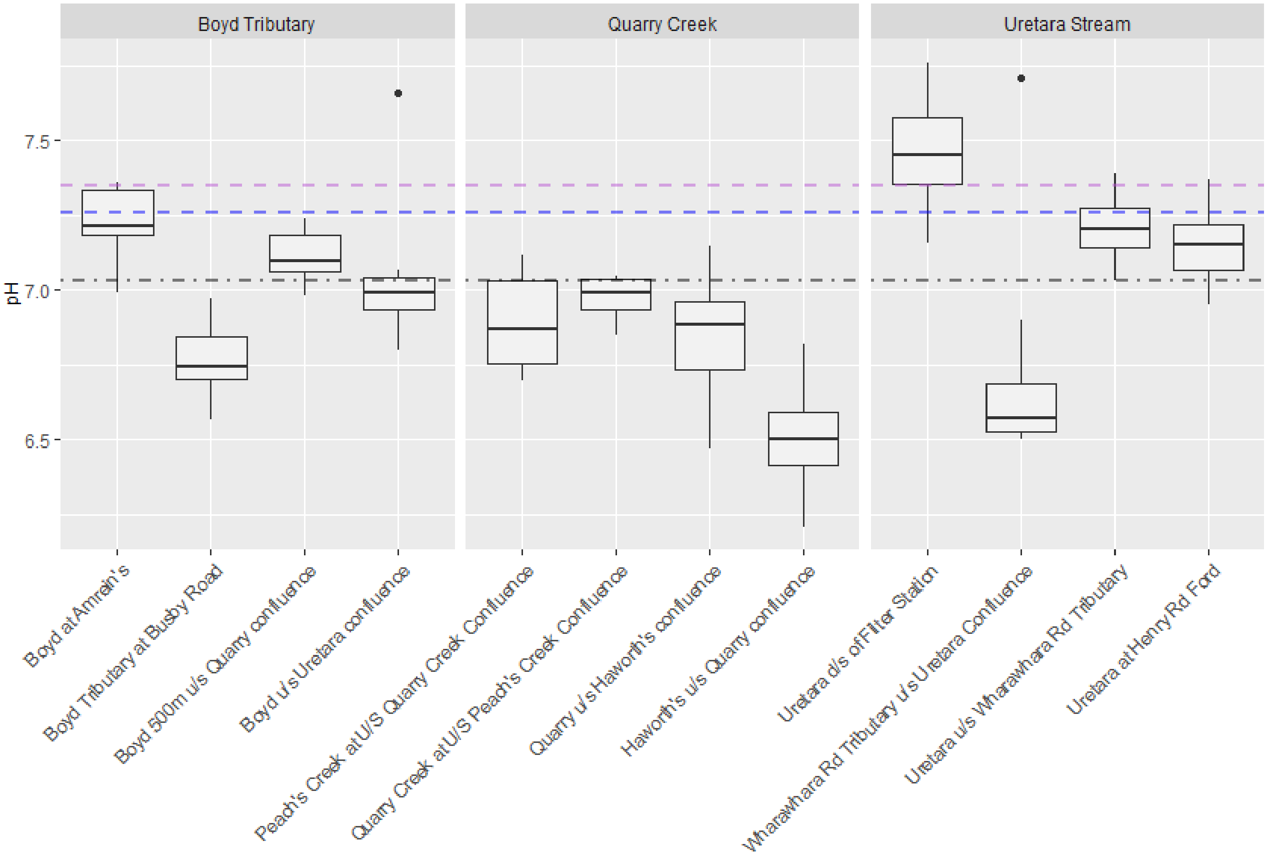

Figure 4-6. pH at monitoring sites between 2018 and 2022. Comparative pH values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

4.6.6 Turbidity

Median turbidity was generally less than the DVG for WWL elevations, apart from 'Peach's Creek at u/s Quarry Creek confluence'. Turbidity readings from this location were consistently above the DGV for turbidity in a WWL and CWH scenario. This location had the greatest overall turbidity reading (169 NTU, 26 January 2022), which was collected within 24 hours of a large rainfall event, the greatest TSS median and maximum, and consistently had the poorest water clarity (m) (Figure 4-8 & Figure 4-9). The other two monitoring sites that had elevated median turbidity were also from the Peach's Creek / Quarry Creek area downstream of the quarry site.

The waterway above the 'Peach's Creek at u/s Quarry Creek confluence' monitoring location flows adjacent to the Swap's Katikati Quarry. Quarrying activities are potentially related to the elevated turbidity measurements in this location.

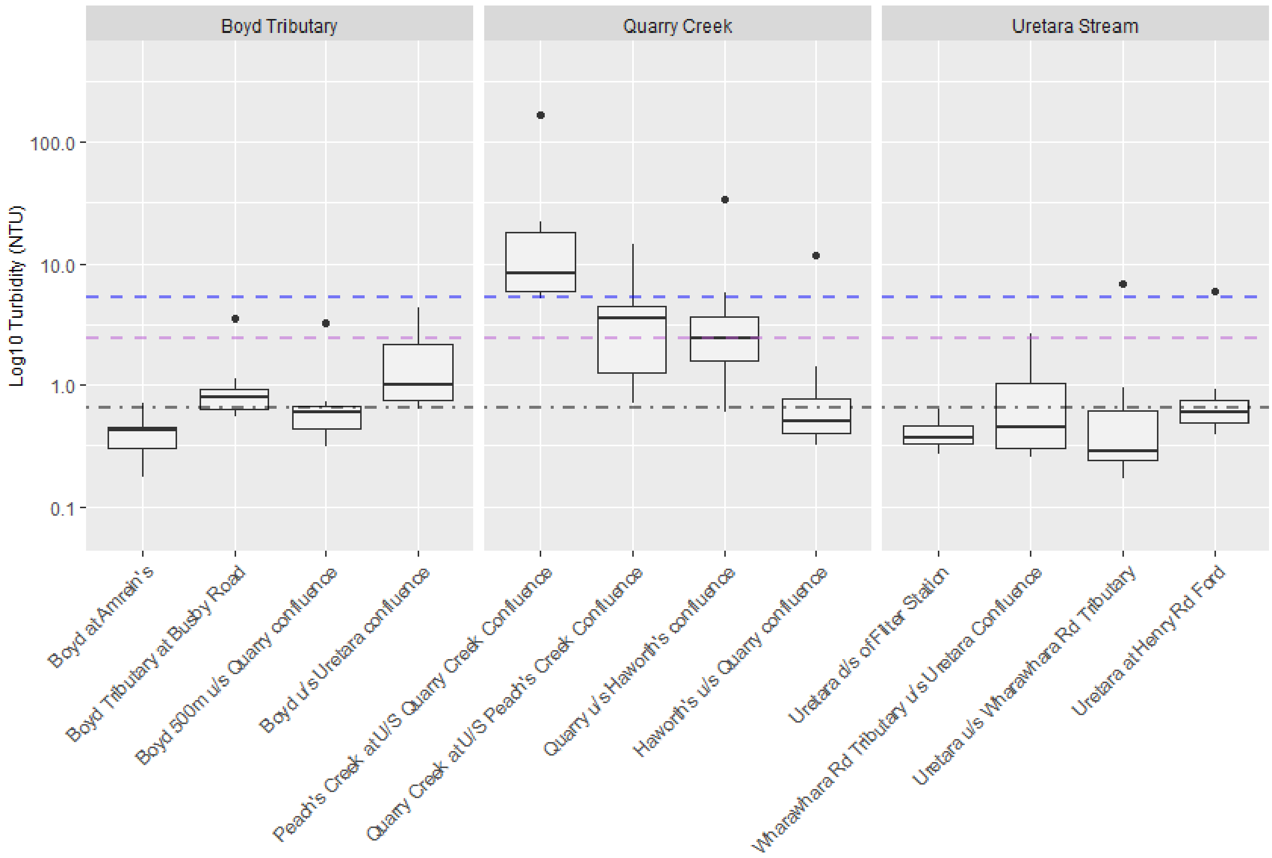

Figure 4-7. Log_{10} Turbidity (NTU) at monitoring sites between 2018 and 2022. Comparative turbidity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

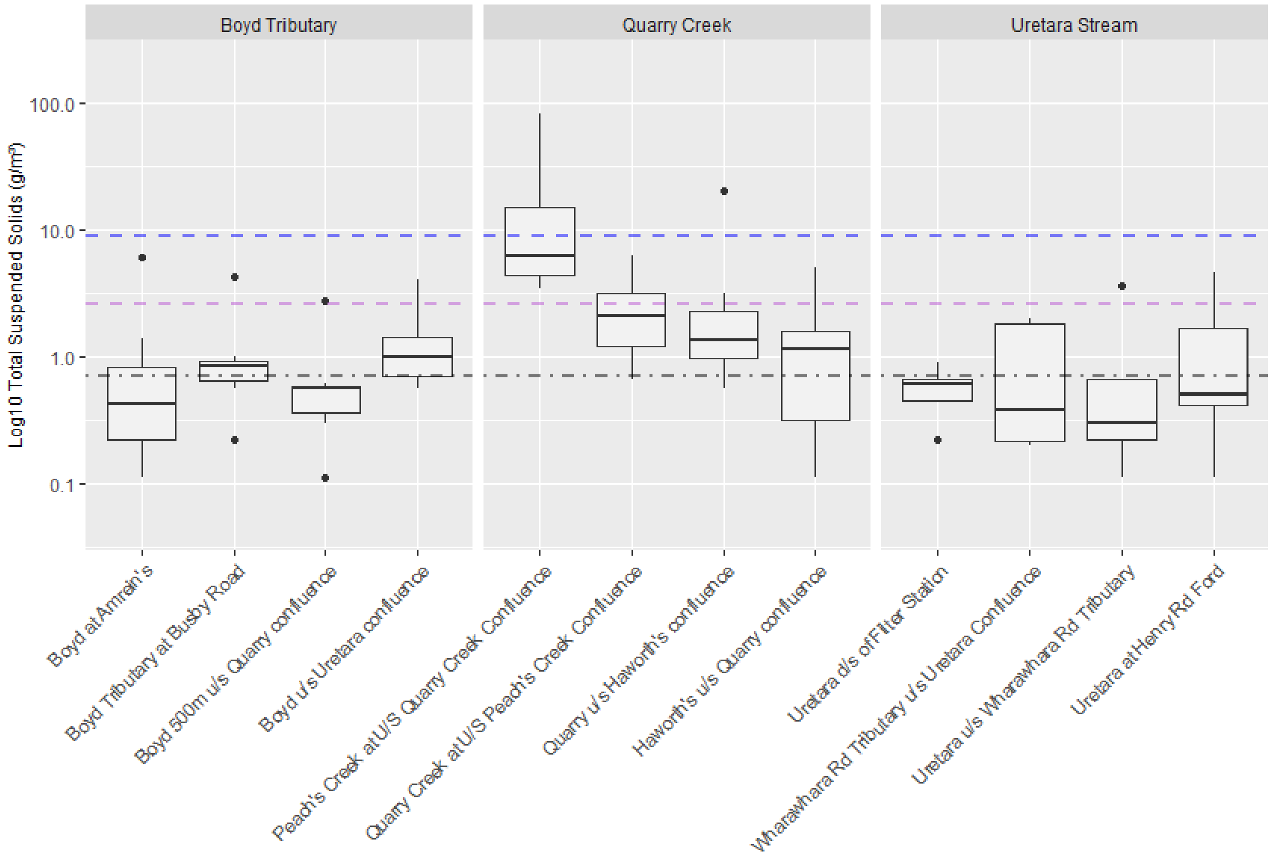

Figure 4-8. Total suspended solids (TSS) at monitoring sites between 2018 and 2022. Comparative TSS values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

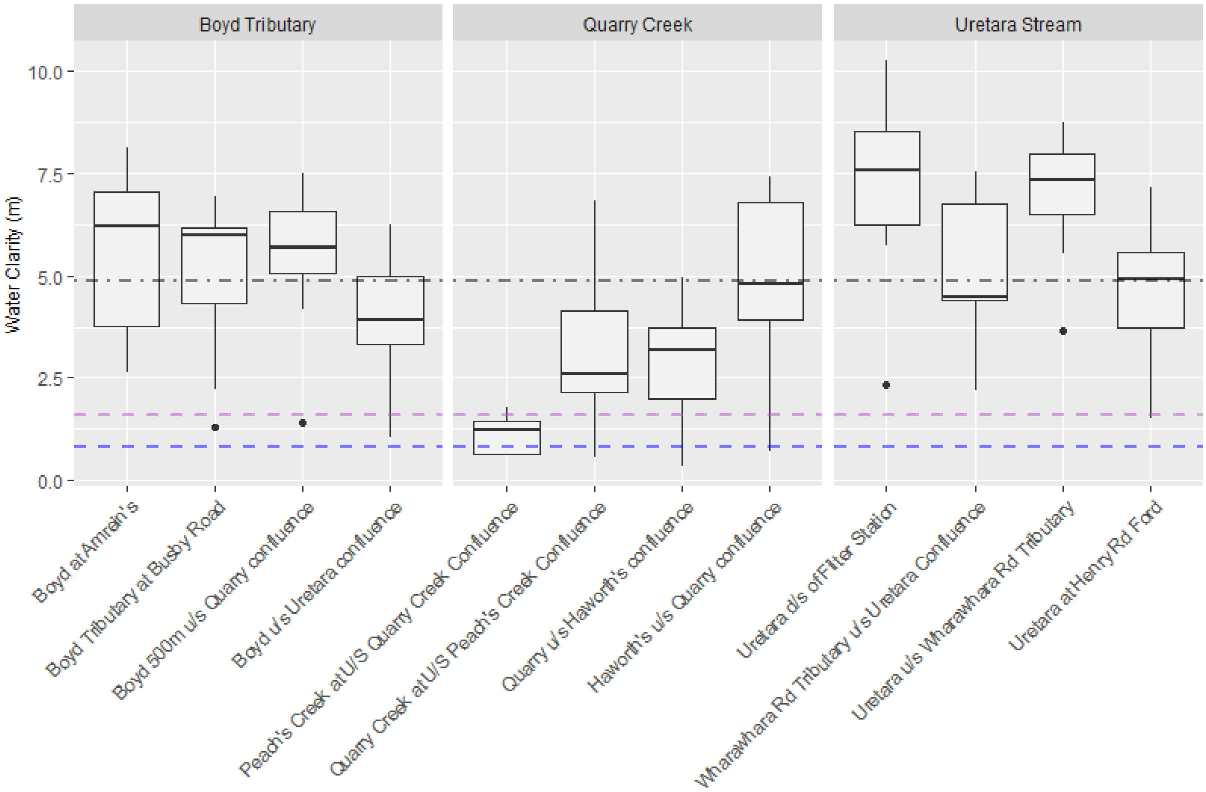

Figure 4-9. Water clarity at monitoring sites between 2018 and 2022. Comparative clarity values shown are the catchment median (grey), the ANZG DGV for warm, wet low elevations (blue), and ANZG DGV for cool wet hill country (pink).

4.6.7 Swimming Site *E. coli* Concentrations – Uretara at Henry Road Ford

Across the 26 sample events that occurred in the Uretara Stream at Henry Road Ford, 46% of *E. coli* concentrations were considered acceptable for swimming. The remainder of sample events indicated that caution should be advised, or the site is not safe for swimming. All of the events in the amber or red category occurred in the summer period (November-April). This is of concern, as the public are more likely to swim/make contact with the water during the summer months.

Table 4-5. Percentage and number of *E. coli* samples from Uretara Stream at Henry Road Ford within the MWQG thresholds, 2018-2022.

MWQG Threshold / Implication	MWQG Numerical Value	Percentage of Events	Number of Events
Acceptable / Safe for swimming	<260 cfu/100 mL	44%	12
Alert / Caution Advised	260-550 cfu/100 mL	30%	8
Action / Unsafe for swimming	>550 cfu/100 mL	26%	7
Total number of events			**27**

The NPSFM 2020 provides attribute bands based on the percentage of exceedances (MfE, 2020). For each attribute band, there is a predicted average *Campylobacter* infection risk. The site falls into attribute band D in the NPSFM attribute states for human contact with *E. coli* in rivers. Within this attribute band, the predicted average infection risk is >3%.

Table 4-6. Classification of the swimming site over the monitoring period (July 2019 – December 2020) from Table 9 of the NPSFM 2020.

% Exceedances > 540 cfu/100 mL	% Exceedances > 260 cfu/100 mL	Median concentration (cfu/100 mL)	95th Percentile (cfu/100 mL)	Attribute Band
26%	56%	295	1300	D (orange)

4.6.8 *E. coli* Concentration – All Monitoring Sites

The median *E. coli* concentrations across 2018 to 2022 monitoring seasons are compared between sites in Figure 4-10. The highest median concentration of *E. coli* (i.e. the worst) was recorded in Quarry Creek upstream of the Boyd Creek confluence. The lowest median concentration of *E. coli* (i.e. the best) was recorded at one of the most upstream sites (Uretara d/s of Filter Station). Median concentrations at other upstream sites (i.e. around the Peach's Creek and Quarry Creek confluence) are considered to be at 'Alert/Caution Advised' level, according to MWQG values. The only location that returned 'Acceptable/Safe for Swimming' results consistently throughout the monitoring period was the 'Uretara at above Boyd Tributary', which is a sample location downstream of the 'Uretara d/s of Filter Station'.

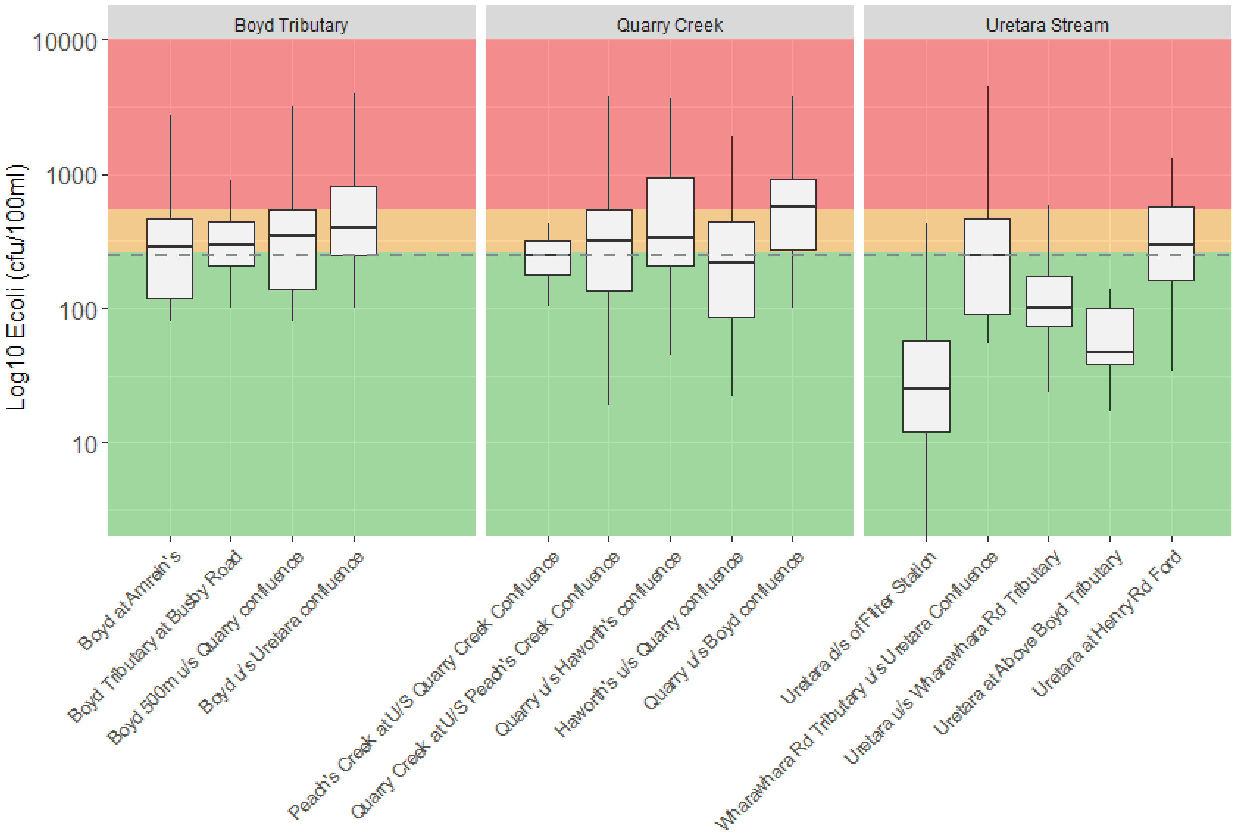

Figure 4-10. E. coli concentrations at monitoring sites from sampling events during 2018 through to 2022. The coloured bands illustrate the E. coli thresholds of the MWQG. Note the Log10 y-axis scale.

For the purposes of assessing the temporal variability of *E. coli* concentrations, the concentrations were divided into 'summer' (i.e. November to April) and 'winter' (i.e. May-October) periods. The results were explored in heat maps for summer and winter, which can be viewed in Figure 4-11 and Figure 4-12, respectively. The colour of the 'bubbles' in the figures indicate which category each monitoring site falls into, on average. The relative size of the 'bubbles' is an arbitrary indication of the 'size' of the concentration within each category.

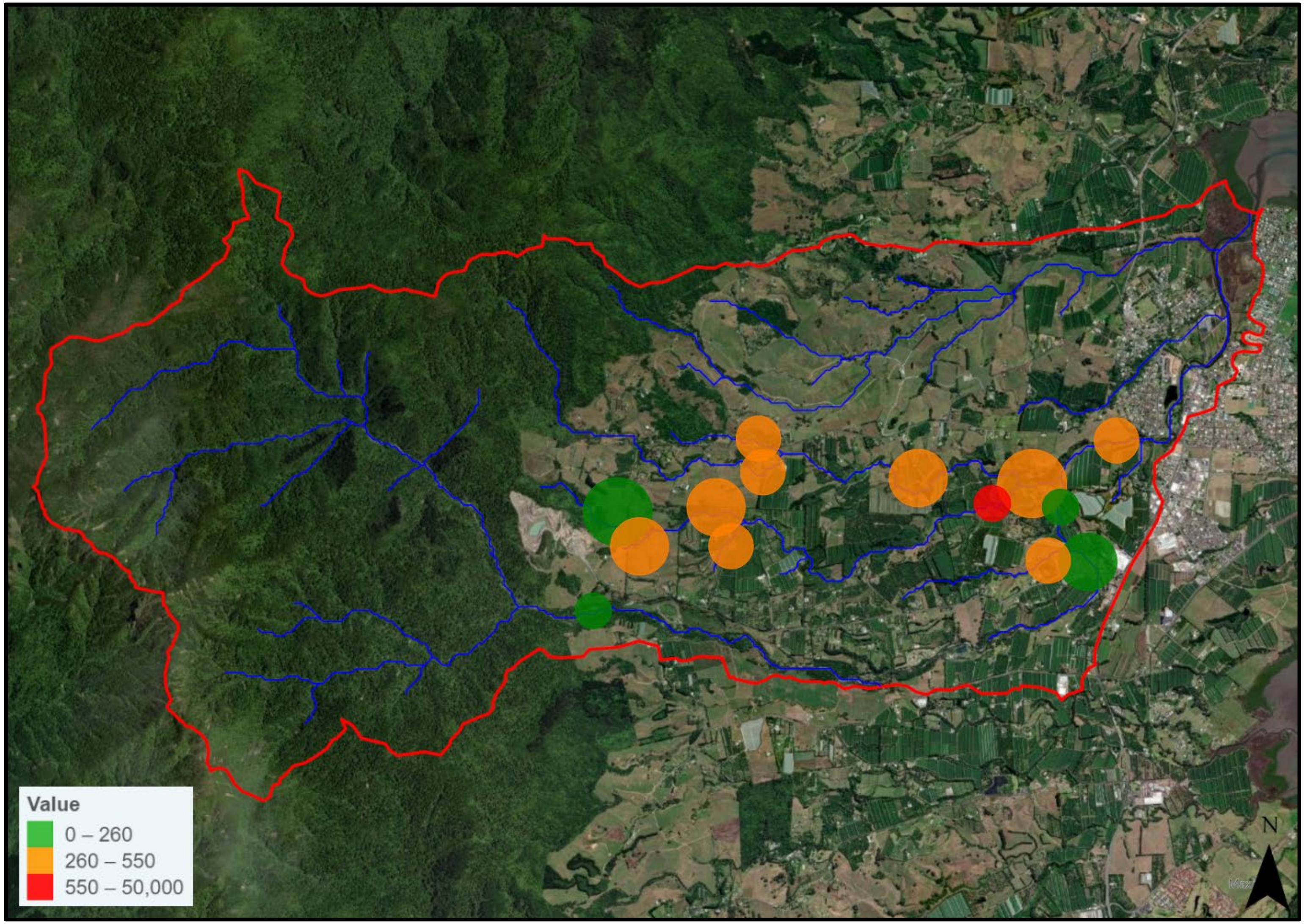

Figure 4-11. A heat map for median relative *E. coli* concentrations (cfu/100 mL) per site in the winter period (May-October) in the Uretara catchment. Green indicates 'Acceptable', orange indicates 'Alert', and red indicates 'unsafe' according to the MWQG (2003). The size of the circles at each location indicate the ‘size’ of concentration value within each concentration range, based on arbitraty divisions of concentrations within each *E. coli* concentration range.

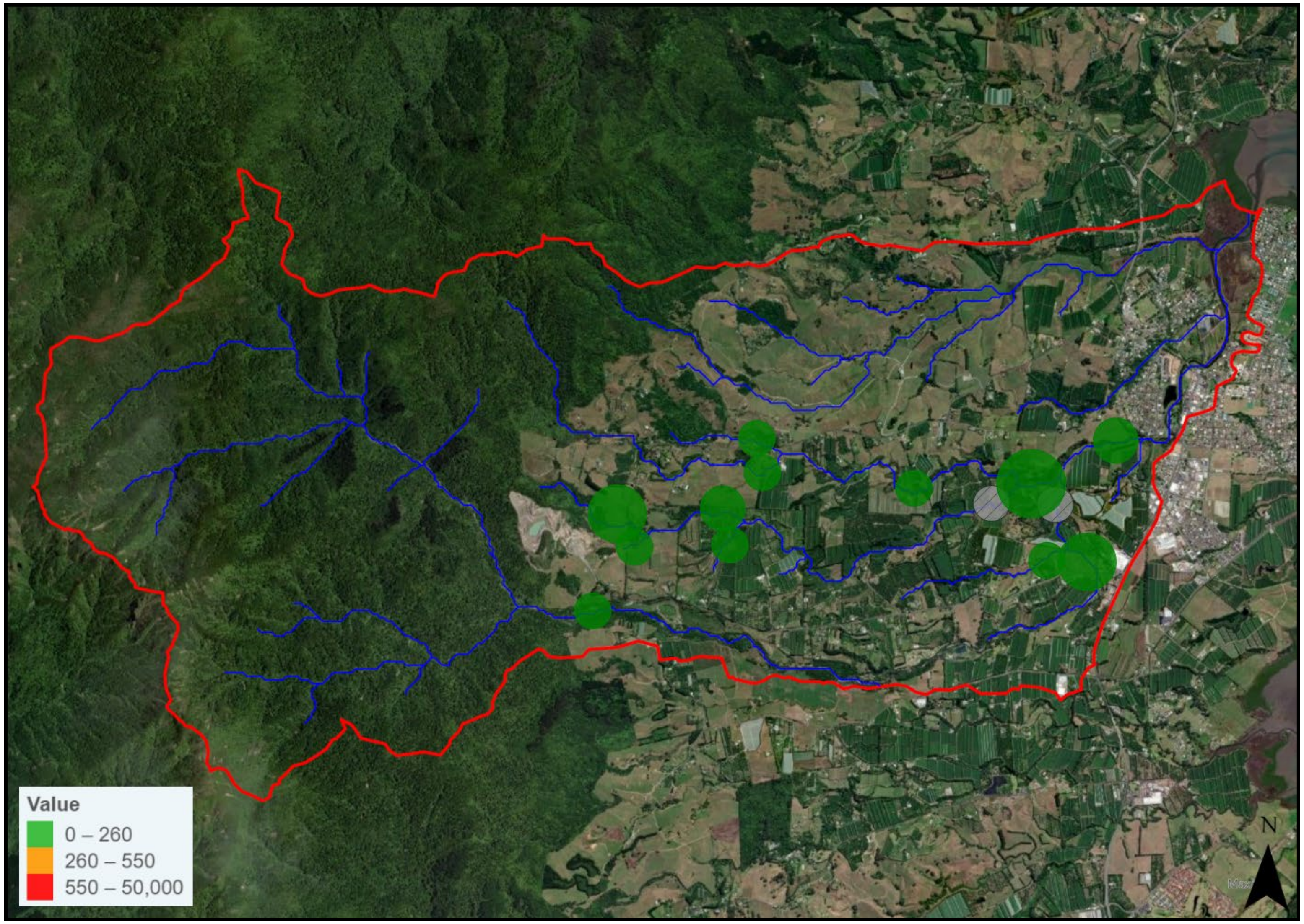

Figure 4-12. A heat map for median relative E. coli concentrations (cfu/100 mL) per site in the winter period (May-October) in the Uretara catchment. Green indicates 'Acceptable', orange indicates 'Alert', and red indicates 'unsafe' according to the MWQG (2003). The size of the circles at each location indicate the 'size' of concentration value within each concentration range, based on arbitraty divisions of concentrations within each *E. coli* concentration range..

Based on the heat maps in Figure 4-11 and Figure 4-12, it appears that the median concentrations in four of the sites are less affected by *E. coli* contamination, and fall within the 'Acceptable' concentration range. However, all other sites fall within either the 'Alert' or 'Unsafe' ranges. Meanwhile, all median values from samples collected in the winter period are considered 'Acceptable'.

The percentage of events within each category per season, across the whole catchment, is shown in Figure 4-13. There were not any concentrations in the 'action/red' category during the winter period, and 9% of events were within the 'alert/amber' category. Meanwhile, there was a more even distribution during the summer period. Of the 2019 summer sample events, 42% were at acceptable levels, 33% were within the 'alert/amber' range, and 25% was considered to be above the 'action/red' level.

When comparing 'summer' versus 'winter' sampling flow and loads, there are two factors to consider. The first is that winter conditions are more likely to dilute nutrient and faecal inputs. The second is that the summer period is more likely to represent 'baseflow' conditions, which is the streamflow that is sustained between precipitation events and is fed by alternate / delayed pathways. The greater concentrations during the summer/baseflow periods may indicate that there is both diffuse runoff (i.e. faecal material transported in runoff) and direct deposition occurring in the catchment.

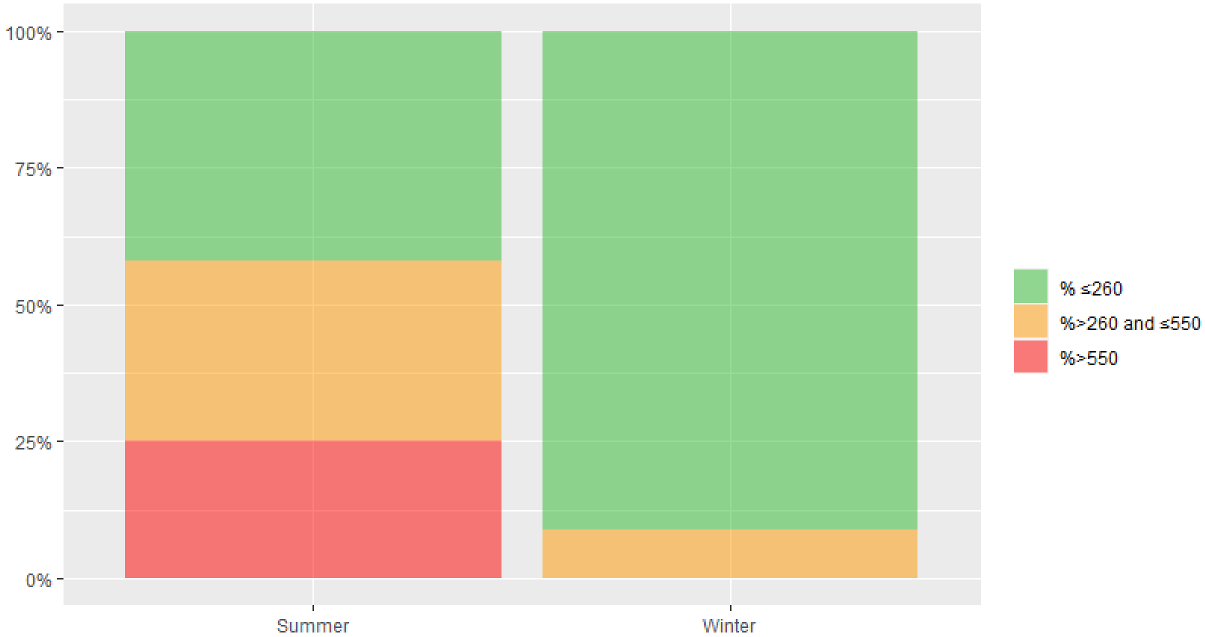

Figure 4-13. Percentage of sample events that fall within each *E. coli* category, categorised as summer (November-April, n=40) and winter (May-October, n=93).

4.6.9 FST

Table 4-7. Faecal source tracking for samples in the Uretara catchment that exceeded 550 cfu/100 mL

Site Name	Date	Human Source?	Ruminant Source?	Proportion Ruminant	Sheep	Cow	Dog	Avian	Conclusion
Boyd East Creek at Uretara Orchard Ltd	19/12/2017	No	Yes	10-50%	N/A	N/A	No	No	Ruminant source (10-50%)
Boyd East Creek at Uretara Orchard Ltd	30/01/2018	No	Yes	1% or less	N/A	N/A	No	Yes	Avian & Ruminant source (1% or less)
Boyd East Creek at U/S Haworth's Creek	30/01/2018	No	Yes	10-50%	N/A	N/A	No	Yes	Ruminant & Avian source (10-50%)
Boyd Tributary at Busby Road	19/12/2017	No	Yes	10-50%	N/A	N/A	No	No	Ruminant source (10-50%)
Boyd Tributary at Busby Road	30/01/2018	No	Yes	1-10%	N/A	N/A	No	No	Ruminant source (1-10%)
Boyd at u/s of Uretara Confluence	30/01/2018	No	No	N/A	N/A	N/A	No	Yes	Avian source
Boyd West Creek 500m u/s Boyd East Confluence	30/01/2018	No	Yes	1% or less	N/A	N/A	No	Yes	Avian & Ruminant source (1% or less)
Boyd West Creek at Amrein's	30/01/2018	No	No	N/A	N/A	N/A	No	Yes	Avian source
Haworth's Creek u/s Boyd East Creek	19/12/2017	No	No	N/A	N/A	N/A	No	No	No conclusion
Haworth's Creek u/s Boyd East Creek	30/01/2018	No	No	N/A	N/A	N/A	No	Yes	Avian source
Peach's Creek at U/S Quarry Creek Confluence	19/12/2017	No	No	N/A	N/A	N/A	No	No	No conclusion

Site Name	Date	Human Source?	Ruminant Source?	Proportion Ruminant	Sheep	Cow	Dog	Avian	Conclusion
Peach's Creek at U/S Quarry Creek Confluence	30/01/2018	No	Yes	10-50%	N/A	N/A	No	No	Ruminant source (10-50%)
Quarry Creek at U/S Peach's Creek Confluence	19/12/2017	No	No	N/A	N/A	N/A	No	No	No conclusion
Quarry Creek at U/S Peach's Creek Confluence	30/01/2018	No	Yes	10-50%	N/A	N/A	No	No	Ruminant source (10-50%)
Uretara d/s of Filter Station	19/12/2017	No	No	N/A	N/A	N/A	No	No	No conclusion
Uretara at Henry Rd Ford	30/01/2018	No	No	N/A	N/A	N/A	No	Yes	Avian source
Uretara at Henry Rd Ford	6/03/2018	No	Yes	1-10%	N/A	N/A	No	Yes	Ruminant (1-10%) & Avian source
Uretara at Henry Rd Ford	19/03/2018	No	No	N/A	N/A	N/A	No	Yes	Avian source

It appears that there is a transition from a ruminant-dominant contamination source in the upper catchment, to a ruminant and / or avian source in the lower catchment / lowland areas.

4.6.10 *E. coli* Load

Load was calculated from the synthetic flow equations presented in Table 4-3, noting that only four of the Uretara sites currently have a calibrated synthetic flow equation. The Boyd Creek site, the Quarry Creek site, and the 'Uretara u/s of Wharawhara Road Tributary' site are upstream sites representing three different branches, and join together approximately 500 m to 800 m downstream of the sites. Prior to their confluence, the Quarry Creek and Boyd Creek sites have estimated *E. coli* loads that did not exceed 1.5 x 10^6 cfu/s, and have similar medians. The Uretara Stream upstream of the Wharawhara Road Tributary showed a higher median load that was twice that of the median from the other two upstream sites. The maximum estimated load was also an order of magnitude greater than the other two sites (1.1 x10^7 cfu/s).

The Uretara Stream at Henry Road Ford site (the most downstream site) is approximately 700 m downstream of the confluence of the other three sites. There is an overall increase in the median load between the three upstream sites and the Henry Road Ford site, with the Henry Road Ford median *E. coli* load being over two times greater than the Uretara u/s Wharawhara Road Tributary site. The maximum load at this site was approximately 2.2 x 10^7 cfu/s.

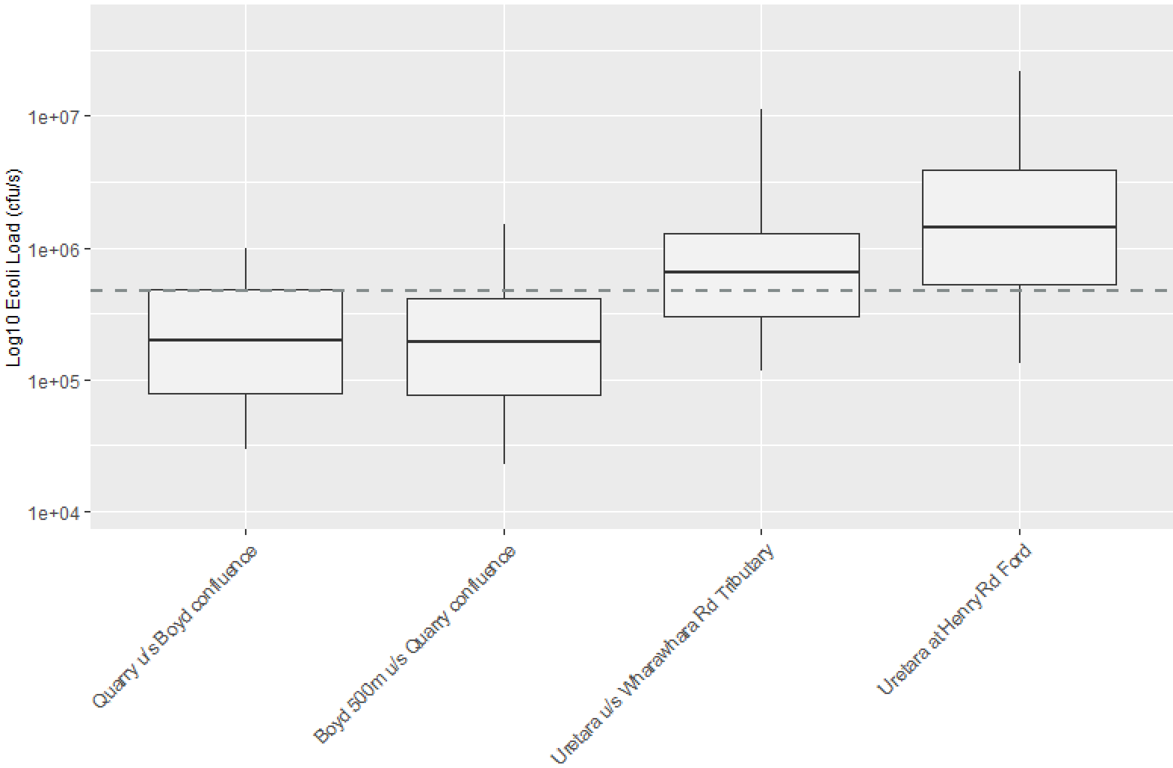

Figure 4-14. Calculated *E. coli* loads using synthetic flow calculations and concentration data collected from 2018 through to 2022. Please note: Synthetic flow calculations have been created for only four of the monitoring sites. The dashed line represents the median load over the entire monitoring period, across all four sites.

4.7 Discussion (Matapakitanga)

E. coli

The Quarry Creek site and Boyd Creek site upstream of their confluence both have mean *E. coli* concentrations within the 'Alert/amber' range (Figure 4-10). However, in terms of load transported by these Creeks, the load is relatively low compared to other sites. This is because the estimated flow from these sites is an order of magnitude smaller than the flow in the Uretara Stream upstream of the Wharawhara Road site, and at the Henry Ford Road site. The Quarry Creek and Boyd Creek introduce *E. coli* to the Uretara Stream, but also do not add a significant level of flow to dilute their contribution.

Previous FST completed in 2020 indicated that the primary faecal source at a number of sites was avian. It was noted that there was a goose colony upstream of the Henry Road Ford site, which was the suspected source of elevated *E. coli* at the swimming site. There are indications in the FST data that suggest that the faecal source transitions to an avian source in the lowland areas. However, the colony was removed, and the *E. coli* levels remained elevated. Additionally, chicken manure application in the lower catchment was previously suspected of being the source of *E. coli*. However, there is no conclusive evidence that removing the manure application has improved local water quality, particularly as the *E. coli* concentrations already appear elevated upstream of the locations where manure was applied.

As stated, the analysis completed in this report indicates that *E. coli* concentrations in water are already elevated in the upstream monitoring sites of Boyd Creek, Boyd Tributary, Peach's Creek, and Quarry Creek. The streams generally begin in indigenous forest and flow through exotic productive grassland prior to the monitoring station. The primary faecal sources identified at these monitoring sites are either ruminant (10-50%) or inconclusive, indicating an agricultural source, or potentially wild deer. Avian sources were not directly identified in the upper catchment samples during FST. However, some FST from these locations was inconclusive, and there has been evidence of a disproportionate amount of Pūkeko DNA in water samples from several locations. Therefore, contribution from birds or other wildlife cannot be ruled out.

In the event that the source is primarily from the farming activities in the upper catchment or just above Henry Road Ford, landowners should be encouraged to fence off the waterways through the properties, create stock exclusion zones, remove cattle crossing areas, and/or introduce riparian planting. Methods like these would reduce the direct deposition of stock faecal matter into the waterways, or provide a buffer for overland flow inputs. According to Collins & Rutherford (2004), median reductions of *E. coli* from 10 m setbacks on hill country land grazed by sheep and beef cattle is approximately 22-35%.

Much like with the suspected goose colony in the lower catchments, it may be prudent to conduct a field survey to identify whether a bird colony (e.g. Pūkeko) or deer have established in the upper catchment. It is noted that a pond / wetland is visible in aerial photography adjacent to Peach's Creek. This may be a point of investigation. Additionally, the FST data for the Uretara catchment shows poor source identification, with many results being inconclusive or <10%. This is an area of study that could be improved upon, as it could help to inform targeted mitigation measures.

4.8 Recommendations (Ngā Tūtohutanga)

Overall, the catchment would benefit from ongoing monitoring and engagement to improve water quality.

i. **Create and refine synthetic flow equations for the other sites in the catchment, to allow for load calculations across the catchment. Alternatively, consider other approaches to estimating flow rates within the catchment.**

   Refining flow measurement would mainly be of benefit to determine relative loads once the primary source of *E. coli* is established. A potential method would be to estimate the ratio of smaller streams to gauged sites, and crudely calibrate a flow model for the catchment. Alternatively, a proportional approach could be used, in line with the work done in the Ngongotahā catchment.

   However, this is not considered a key action at this stage of data collection.

ii. **Investigate *E. coli* sources within the indigenous forest upstream of the Boyd Tributary, Peach's Creek and Quarry Creek, and potential avian sources in the lowland areas.**

   Carry out a site walkover of the upper reaches of the creeks and tributary, to assess whether there are any established colonies or evidence of wildlife that are contributing to *E. coli* loads in the indigenous forest. The wetland upstream of Peach's Creek monitoring site should be investigated.

   There are indications of an avian faecal source, particularly in the lower monitoring area at Henry Road Ford. Additional lowland surveys may be beneficial. However, previous initiatives (i.e. goose colony culling and manure management) does not appear to have a conclusive influence.

iii. **Further investigation into *E. coli* sources in the Uretara catchment.**

   It may be prudent to conduct a specific programme for FST data in the Uretara catchment. Based on the FST data presented, many samples do not provide any conclusive source of faecal contamination or can only account for a small percentage of the source. Having a stronger understanding of the source may improve the ability to create a targeted mitigation strategy. One method would be to filter a larger volume of water to increase the amount of sample to analyse.

iv. **Specifically, investigate *E. coli* sources in the farmland upstream of the Peach's Creek, Boyd Tributary, Boyd Creek and Quarry Creek sites, and support Land Management Officers to engage with the community/land managers to explore water quality measures.**

   As ruminant sources have been identified, mitigation measures in the farmland between the forest and the first monitoring sites should be investigated and encouraged. These include:

   - Riparian planting,
   - Creating exclusion zones, fencing, and reducing the number of stock crossings in streams,
   - Introducing and encouraging best practice around farm dairy effluent management and discharge to waterways

   Additionally, current *E. coli* results show that *E. coli* concentrations in the summer periods are greater than in the winter periods. This is either due to the effects of dilution, or may suggest that direct deposition of faecal matter into waterways is occurring. By encouraging and instigating stock exclusion measures, further monitoring may be able to identify whether this was a primary source of *E. coli* loads during the summer months.

v. **Investigate mitigation measures between the Quarry on Wharawhara Road and Peach's Creek/Quarry Creek**

The median sediment load into Peach’s Creek and Quarry Creek is the greatest in the catchment. They are adjacent to an active quarry, and may be negatively affected by the soil disturbance activities occurring. An investigation should be carried out to identify potential sediment loss pathways, and sediment mitigation measures should be explored between the Quarry and creeks.

4.9 Conclusion (Whakakapinga)

The Uretara Stream swimming site at Henry Road Ford regularly exceeds accepted swimmability standards for *E. coli* in water. Monitoring has been carried out across the catchment in order to identify the source of faecal contamination and inform further actions, to improve water quality enough to reduce downstream effects at the swimming sites and beyond.

The present study suggests that concentrations are elevated at upstream sites. However, the *E. coli* load was less from these sites, due to the low flow from them. The Henry Road Ford site represents both high concentration and high load, from both avian and ruminant sources. There is also an indication that activities around Peach’s Creek and Quarry Creek are affecting water quality. There is elevated turbidity and suspended sediment at these locations, and reduced water clarity.

To improve downstream quality, the upper catchment may require more intensive assessment and sampling and the contribution from outside the catchment may need to be quantified, so that targeted mitigation can occur at the identified source. There are also locations along the waterways that may benefit from mitigation measures, such as riparian planting, exclusion zones, and fencing, to minimise contributions.

Appendix B: Uretara Catchment

Overall Summary Statistics

Table B-1. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max	SE mean
Ammoniacal N (g/m^3)	253	0	0.003	0.005	0.0066	0.0073	0.101	0.00054
Conductivity (us/cm)	93	55.2	62.4	67.3	71.13	73.8	188.5	1.61923
DO Sat (%)	240	60.3	94.8	98.1	97.13	101.4	129	0.5087
DRP (g/m^3)	253	0.0003	0.0027	0.004	0.005024	0.006	0.023	0.00023
E coli (g/m^3)	265	2	100	250	519.3	480	9200	58.9
N total (g/m^3)	253	0.0365	0.184	0.341	0.4191	0.521	2.801	0.02399
Nitrate nitrate (as N) (g/m^3)	253	0.007	0.119	0.284	0.3526	0.46	2.417	0.02146
O_2 (g/m^3)	240	5.49	8.975	9.6	9.473	10.062	12.1	0.06191
Total P (g/m^3)	253	0.0009	0.0066	0.0106	0.01378	0.015	0.323	0.00140
pH	93	6.21	6.8	7.03	6.997	7.19	7.76	0.03247
Total suspended solids (g/m^3)	93	0	0.3333	0.7	2.6014	2	82.5	0.92519
Turbidity (NTU)	93	0.17	0.431	0.646	4.061	2.14	169	1.85727
Water Temperature (°C)	240	10.4	15	16.9	16.62	18.3	22.4	0.15912
Water Clarity (m)	92	0.3345	2.8437	4.8865	4.7932	6.7546	10.2538	0.24530

Uretara Downstream of the Filter Station

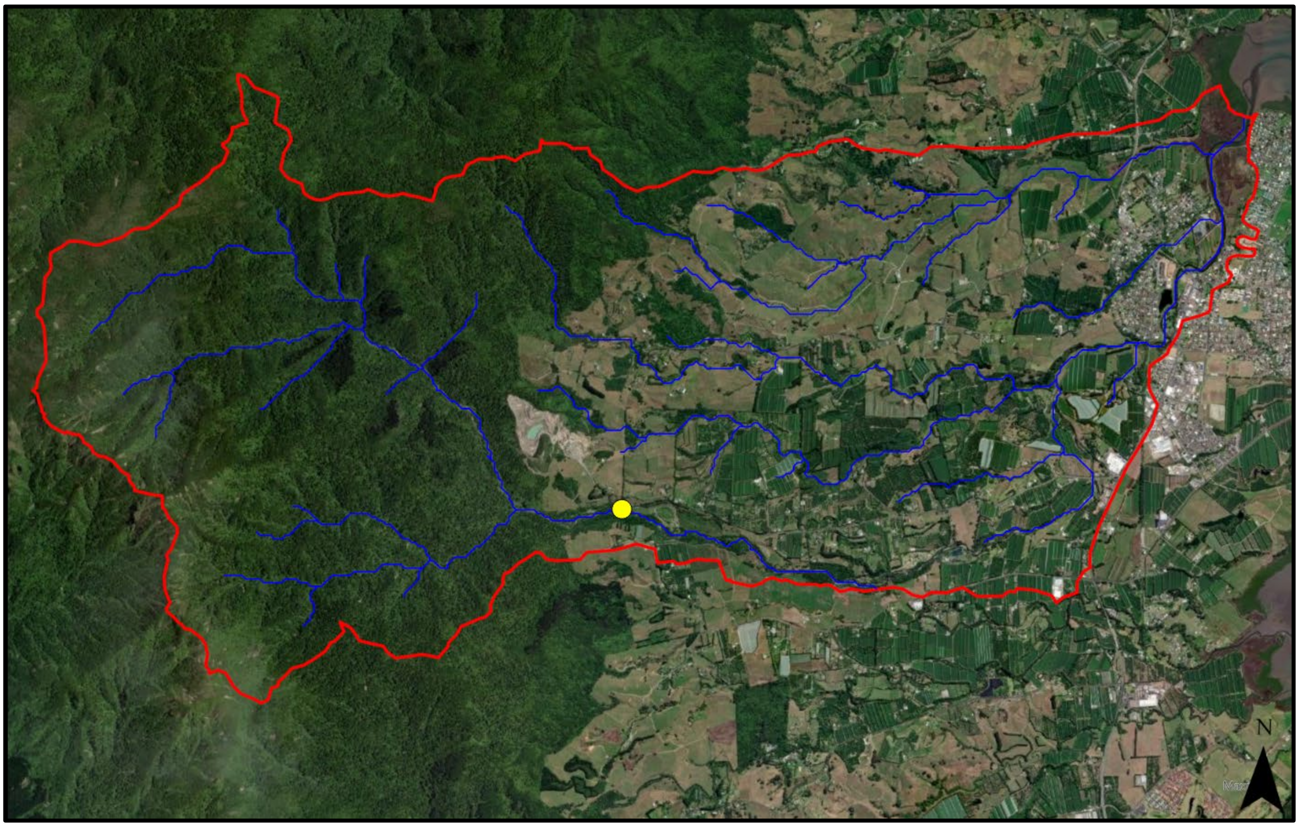

Figure B-1. Location of monitoring site in Uretara Stream, downstream of the Filter Station

Summary statistics

Table B-2. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0	0.003	0.004	0.00373	0.00433	0.0084
Conductivity (us/cm)	8	59.4	64.7	67.95	81.67	71	188.5
DO Sat (%)	19	98.7	100.3	102	103.3	106.1	110
DRP (g/m³)	20	0.003	0.0043	0.006	0.00609	0.008	0.01
E coli (g/m³)	21	2	12	25	63.48	58	430
N total (g/m³)	20	0.0365	0.05595	0.0645	0.07419	0.087	0.1414
Nitrate nitrate (as N) (g/m³)	20	0.016	0.028	0.0372	0.04011	0.048	0.0737
O_2 (g/m³)	19	9.36	9.875	10.2	10.179	10.39	11.25
Total P (g/m³)	20	0.0037	0.0059	0.01	0.01	0.0125	0.018
pH	8	7.16	7.357	7.45	7.457	7.577	7.76
Total suspended solids (g/m³)	8	0	0	0.3333	0.3528	0.6167	0.8889
Turbidity (NTU)	8	0.265	0.3312	0.3655	0.4093	0.4632	0.64
Water Temperature (°C)	19	10.6	14.3	16.3	15.76	17.5	19.9
Water Clarity (m)	8	2.325	6.26	7.571	7.182	8.549	10.254

State of the site

Microbiological guidelines assessment

Table B-3 contains the *E. coli* data assessed against the ‘Surveillance, alert, and action level’ framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall percentage of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-3. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	17	36	15	2	0
Winter	4	4.5	4	0	0
All samples	21	25	19	2	0

Peach’s Creek Upstream of the Quarry Creek Confluence

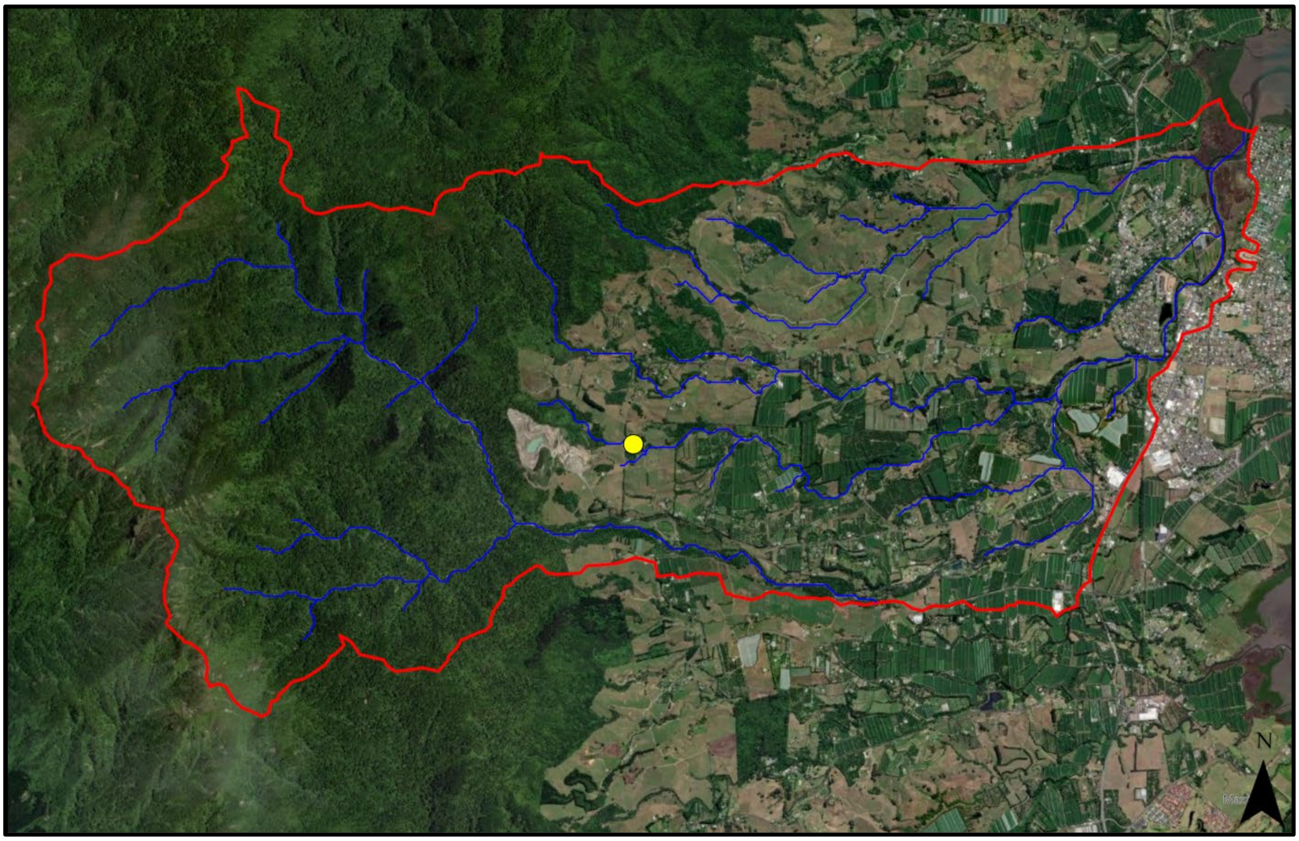

Figure B-2. Location of monitoring site at Peach’s Creek upstream of the Quarry Creek confluence

Summary statistics

Table B-4. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	18	0	0.00248	0.004	0.00389	0.006	0.0076
Conductivity (us/cm)	6	71.3	78.58	82.55	82.2	87.88	89.9
DO Sat (%)	17	88.8	94.6	97.9	97.77	99.8	105.1
DRP (g/m³)	18	0.0025	0.00525	0.0125	0.01056	0.014	0.018
E coli (g/m³)	19	24	180	250	352.5	320	2000
N total (g/m³)	18	0.34	0.3558	0.466	0.7771	1.0975	2.442
Nitrate nitrate (as N) (g/m³)	18	0.305	0.3357	0.44151	0.00389	0.9756	2.4170
O_2 (g/m³)	17	8.52	9.15	9.68	9.552	9.81	10.55
Total P (g/m³)	18	0.004	0.01925	0.02055	0.02387	0.025	0.0973
pH	6	6.7	6.755	6.870	6.893	7.03	7.12
Total suspended solids (g/m³)	6	3.444	4.317	6.5	20.209	15.667	82.5
Turbidity (NTU)	6	5.07	5.897	8.335	36.402	19.023	169
Water Temperature (°C)	17	12.8	15.8	16.3	16.3	17.4	18.7
Water Clarity (m)	5	0.5944	0.6252	1.2331	1.1334	1.4511	1.7635

State of the site

Microbiological guidelines assessment

Table B-5 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall percentage of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-5. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	255	8	6	2
Winter	3	110	3	0	0
All samples	19	250	11	6	2

Quarry Creek Upstream of the Peach's Creek Confluence

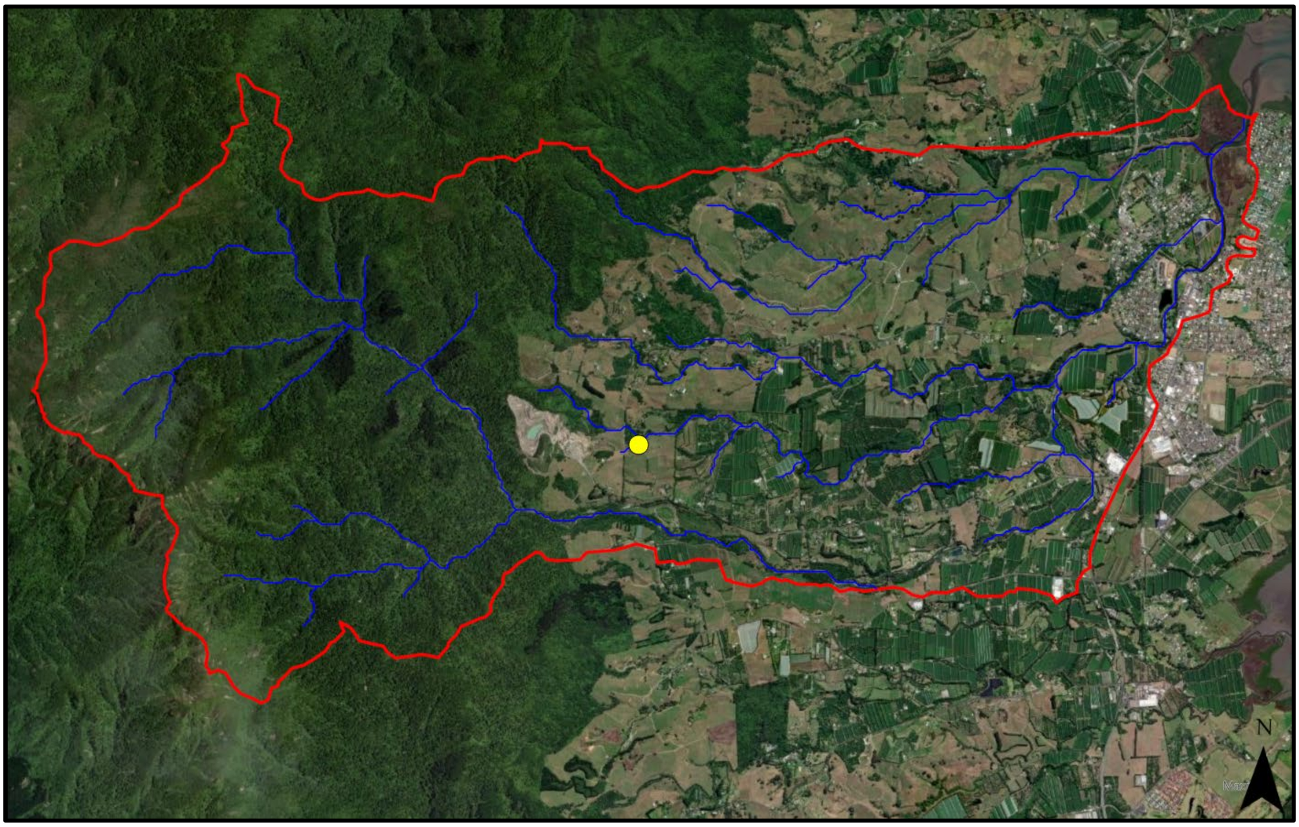

Figure B-3. Location of monitoring site in Quarry Creek upstream of the Peach's Creek confluence

Summary statistics

Table B-6. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	19	0.00	0.0028	0.005	0.00718	0.008	0.046
Conductivity (us/cm)	7	61.5	64.25	73	69.43	74.25	74.5
DO Sat (%)	18	83.9	94.15	96.3	95.54	97.45	105
DRP (g/m^3)	19	0.004	0.00775	0.0094	0.0112	0.01415	0.023
E coli (g/m^3)	19	19	135	320	998.1	540	9200
N total (g/m^3)	19	0.399	0.6039	0.7680	0.9726	1.2285	2.8010
Nitrate nitrate (as N) (g/m^3)	19	0.304	0.5616	0.6869	0.8011	0.9730	1.6190
O_2 (g/m^3)	18	7.6	8.672	9.3	9.217	9.620	10.51
Total P (g/m^3)	19	0.0106	0.0155	0.022	0.04551	0.0515	0.323
pH	7	6.85	6.935	6.99	6.976	7.035	7.05
Total suspended solids (g/m^3)	7	0.6667	1.2167	2.1111	2.5349	3.1667	6.2
Turbidity (NTU)	7	0.705	1.347	3.5	4.336	4.525	14.4
Water Temperature (^{o}C)	18	13.1	15.03	17.5	17.01	18.75	20.5
Water Clarity (m)	7	0.5477	2.151	2.5859	3.2170	4.1260	6.8316

State of the site

Microbiological guidelines assessment

Table B-7 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-7. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	440	5	7	4
Winter	3	47	3	0	0
All samples	19	320	8	7	4

Boyd Tributary at Amrein's

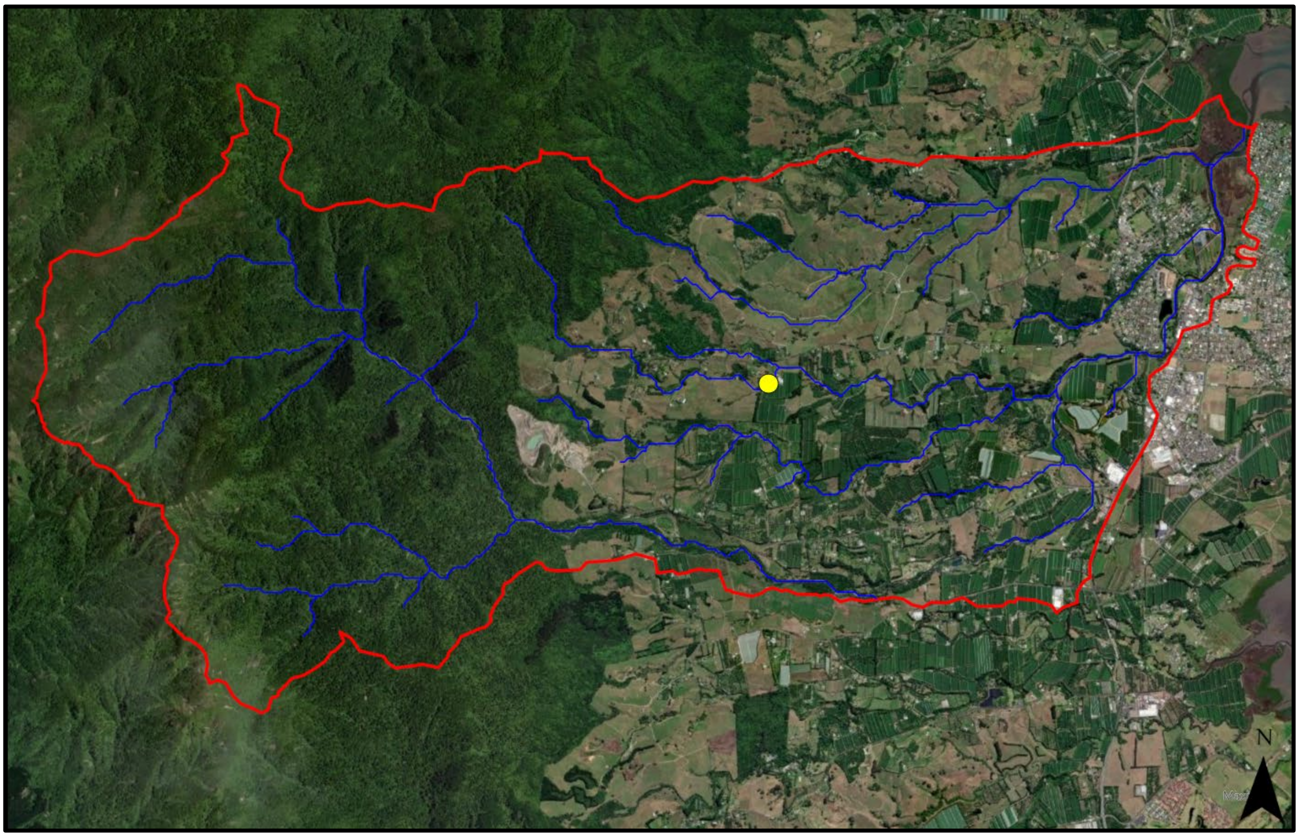

Figure B-4. Location of monitoring site in Boyd Tributary at Amrein's

Summary statistics

Table B-8. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0.001	0.00288	0.005	0.00684	0.00623	0.0473
Conductivity (us/cm)	8	55.2	61.42	63.1	63.31	64.7	73.6
DO Sat (%)	19	91.6	98.2	100.8	100.6	102.6	111.8
DRP (g/m³)	20	0.0037	0.0041	0.005	0.00587	0.00678	0.013
E coli (g/m³)	21	13	120	290	478.7	470	2700
N total (g/m³)	20	0.0662	0.1067	0.1775	0.1699	0.2124	0.3650
Nitrate nitrate (as N) (g/m³)	20	0.022	0.03875	0.09350	0.11414	0.16168	0.305
O_2 (g/m³)	19	8.36	9.405	9.860	9.854	10.390	11.25
Total P (g/m³)	20	0.0053	0.00875	0.011	0.01078	0.0125	0.017
pH	8	6.99	7.185	7.215	7.228	7.335	7.36
Total suspended solids (g/m³)	8	0.1111	0.2222	0.4222	1.1983	0.8688	6.1111
Turbidity (NTU)	8	0.175	0.3025	0.43	0.4052	0.4555	0.7050
Water Temperature (°C)	19	11.3	15.05	16.6	16.43	18.3	20.40
Water Clarity (m)	8	2.635	3.761	6.197	5.626	7.044	8.143

State of the site

Microbiological guidelines assessment

Table B-9 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-9. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	17	330	6	8	3
Winter	4	85	4	0	0
All samples	21	290	10	8	3

Boyd Tributary at Busby Row

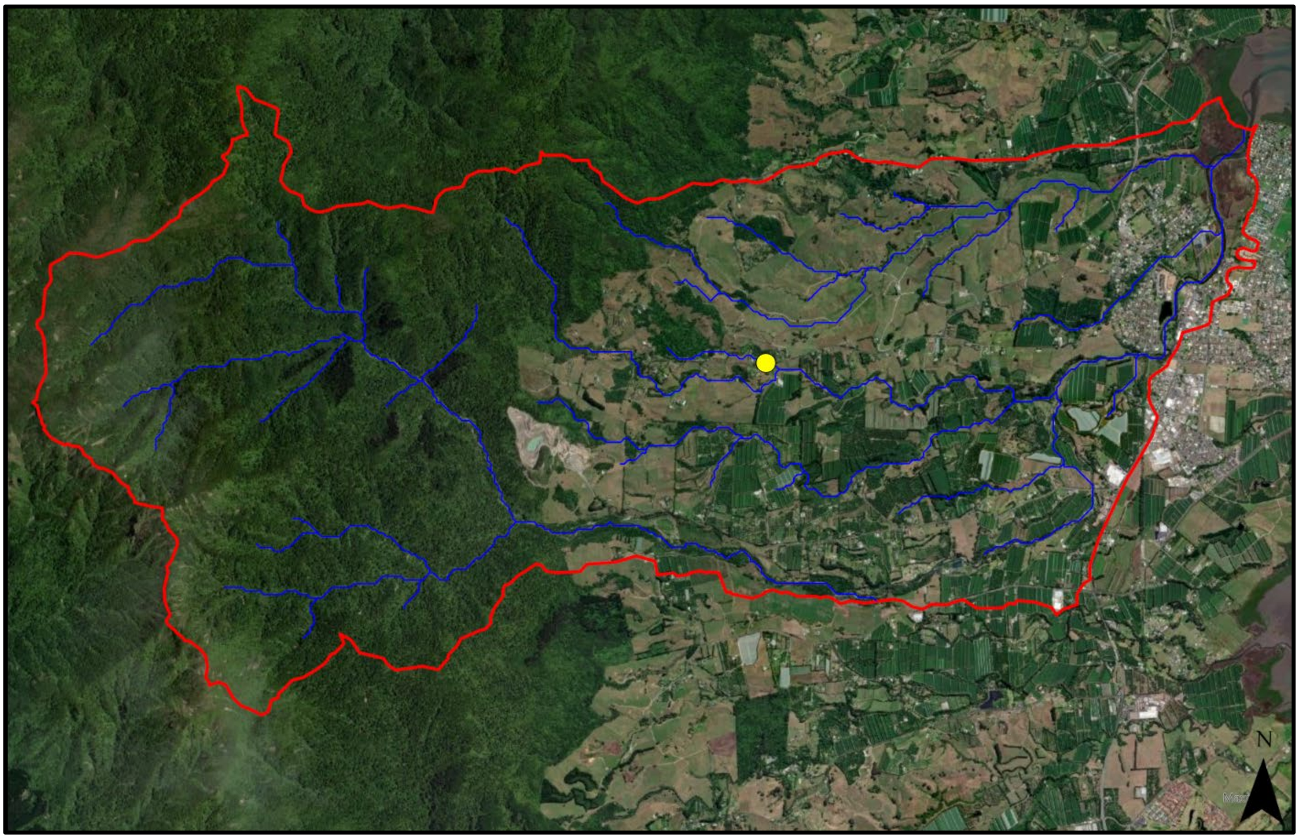

Figure B-5. Location of monitoring site in Boyd Tributary at Busby Row

Summary statistics

Table B-10. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	20	0	0.00345	0.0052	0.00547	0.00678	0.015
Conductivity (us/cm)	8	55.3	57.12	60.65	61.61	65.35	71.6
DO Sat (%)	19	90	95.7	97.0	97.17	98.75	106
DRP (g/m^3)	20	0.0015	0.002	0.003	0.00340	0.00425	0.007
E coli (g/m^3)	21	33	210	300	623.6	440	5300
N total (g/m^3)	20	0.191	0.239	0.29	0.304	0.3512	0.5607
Nitrate nitrate (as N) (g/m^3)	20	0.109	0.2233	0.257	0.2532	0.302	0.3740
O_2 (g/m^3)	19	8.37	9.28	9.65	9.638	10.075	10.67
Total P (g/m^3)	20	0.0024	0.005	0.009	0.00906	0.013	0.0197
pH	8	6.57	6.705	6.745	6.774	6.845	6.97
Total suspended solids (g/m^3)	8	0.2222	0.6389	0.8444	1.1649	0.925	4.2857
Turbidity (NTU)	8	0.545	0.6272	0.797	1.1009	0.9217	3.48
Water Temperature (^{o}C)	19	11.1	14.05	15.9	15.73	17.4	18.9
Water Clarity (m)	8	1.311	4.331	5.972	5.015	6.166	6.943

State of the site

Microbiological guidelines assessment

Table B-11 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-11. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	17	51	5	8	4
Winter	4	310	3	1	0
All samples	21	300	8	9	4

Quarry Creek upstream of Haworth's Confluence

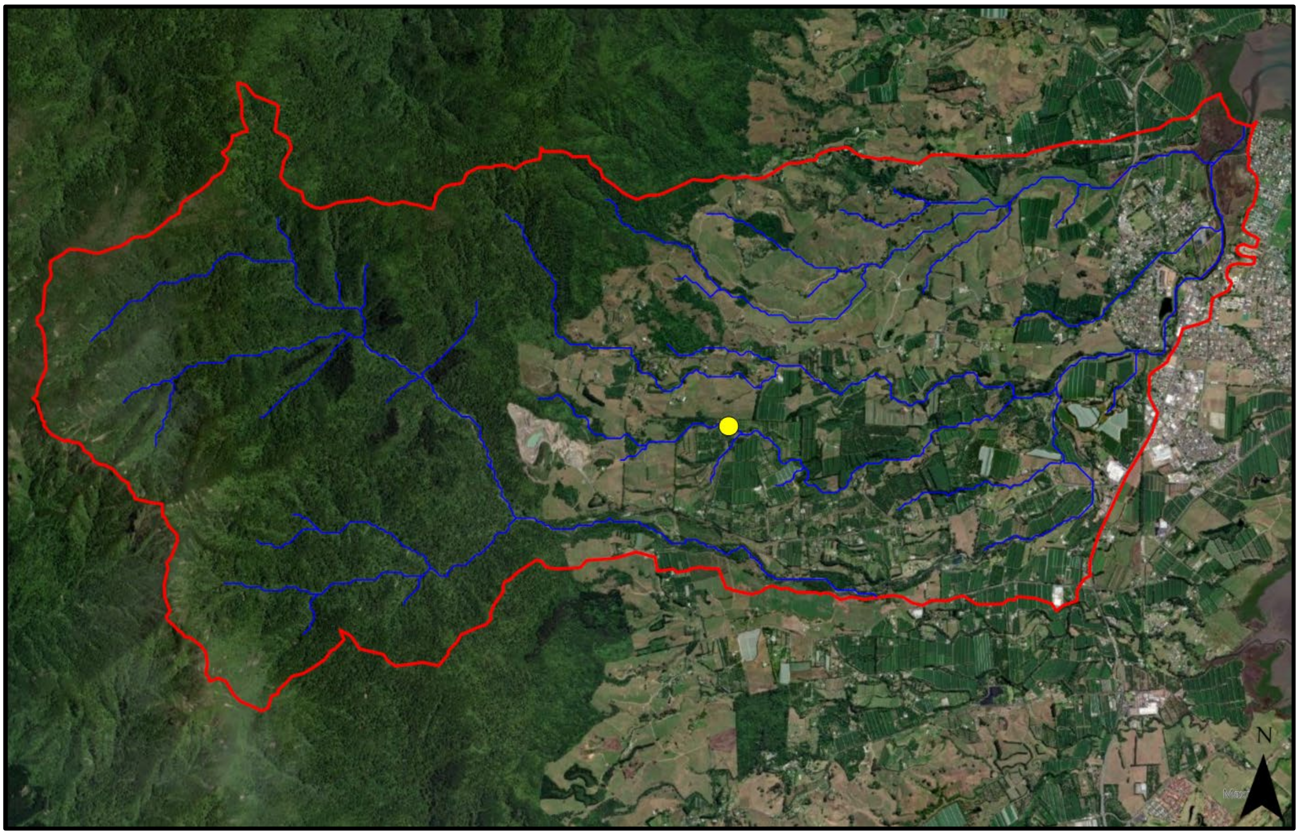

Figure B-6. Location of monitoring site in Quarry Creek upstream of Haworth's confluence

Summary statistics

Table B-12. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0.003	0.004	0.0055	0.00568	0.00625	0.011
Conductivity (us/cm)	8	61.4	61.55	66.9	65.75	68.3	70.2
DO Sat (%)	19	90.6	94.5	96	96.14	98.25	102.3
DRP (g/m³)	20	0.0007	0.00293	0.0031	0.00368	0.00425	0.007
E coli (g/m³)	21	45	210	340	778.8	940	3700
N total (g/m³)	20	0.2964	0.3407	0.4835	0.5561	0.6131	1.867
Nitrate nitrate (as N) (g/m³)	20	0.22	0.3165	0.4308	0.5029	0.5911	1.75
O_2 (g/m³)	19	8.45	8.885	9.42	9.391	9.835	10.45
Total P (g/m³)	20	0.0036	0.006625	0.0105	0.014695	0.01725	0.061
pH	8	6.47	6.735	6.885	6.848	6.963	7.15
Total suspended solids (g/m³)	8	0.5556	0.9722	1.3556	3.8083	2.2778	20.2
Turbidity (NTU)	8	0.591	1.762	2.43	6.415	3.785	34.2
Water Temperature (°C)	19	11.5	14.9	17	16.54	18.4	19.9
Water Clarity (m)	8	0.3345	1.9879	3.1823	2.8915	3.7311	4.955

State of the site

Microbiological guidelines assessment

Table B-13 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-13. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	17	51	5	8	4
Winter	4	310	3	1	0
All samples	21	300	8	9	4

Haworth's Creek upstream of Quarry Creek Confluence

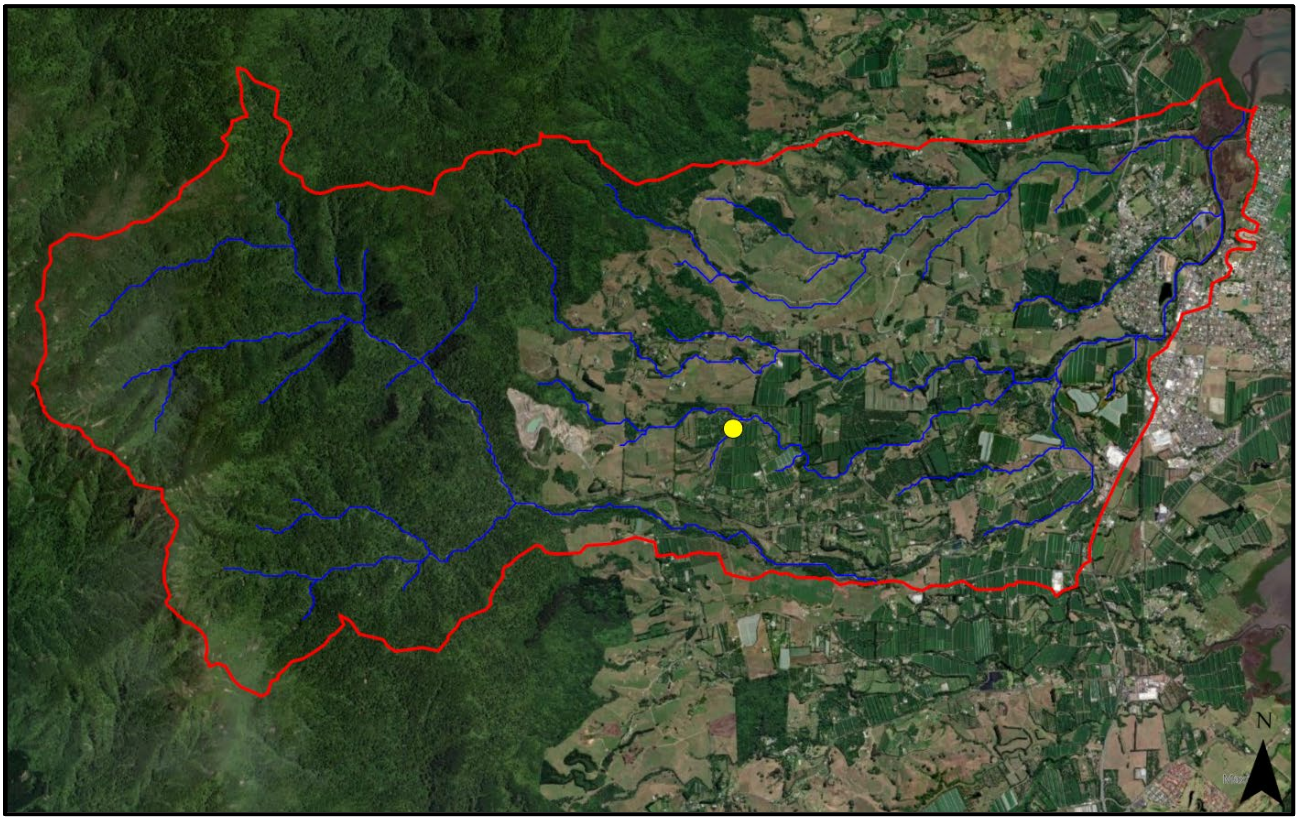

Figure B-7. Location of monitoring site in Haworth's Creek upstream of Quarry Creek confluence

Summary statistics

Table B-14. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	20	0.003	0.008	0.0102	0.01068	0.01325	0.017
Conductivity (us/cm)	8	58.7	60.88	63.5	65.09	69.03	76
DO Sat (%)	19	69.5	83.4	89	88.56	94.25	102
DRP (g/m^3)	20	0.0008	0.001	0.002	0.00194	0.00225	0.00430
E coli (g/m^3)	21	22	87.25	220	408.3	450	1900
N total (g/m^3)	20	0.2942	0.4027	0.5165	0.5506	0.6825	0.96
Nitrate nitrate (as N) (g/m^3)	20	0.1978	0.3222	0.4499	0.4671	0.6112	0.84
O_2 (g/m^3)	19	6.63	7.915	8.8	8.719	9.7	10.19
Total P (g/m^3)	20	0.0009	0.005	0.0065	0.00768	0.01025	0.0173
pH	8	6.21	6.418	6.5	6.514	6.593	6.82
Total suspended solids (g/m^3)	8	0.1111	0.3611	1.1667	1.4948	1.6562	5
Turbidity (NTU)	8	0.3160	0.4062	0.4985	1.9846	0.8397	11.7
Water Temperature (^{o}C)	19	11.6	14.8	16.6	16.35	17.7	20.2
Water Clarity (m)	8	0.7224	3.901	4.816	4.7756	6.7973	7.4239

State of the site

Microbiological guidelines assessment

Table B-15 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-15. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	305	7	5	4
Winter	4	45	4	0	0
All samples	20	220	11	5	4

Boyd Tributary 500 m upstream of Quarry Creek Confluence

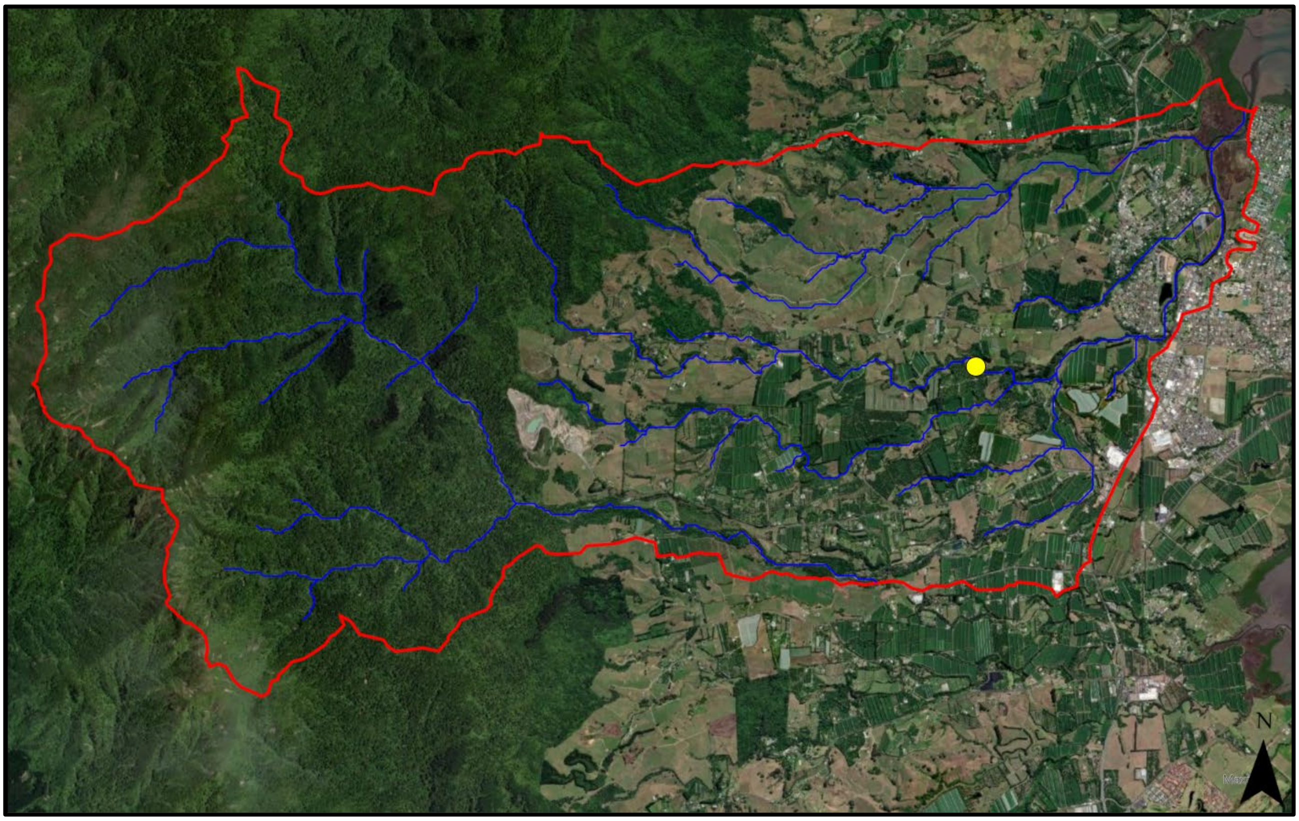

Figure B-8. Location of monitoring site in Boyd Tributary 500 m upstream of Quarry Creek confluence

Summary statistics

Table B-16. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	20	0.0017	0.00375	0.00555	0.00554	0.00718	0.009
Conductivity (us/cm)	8	58.2	63.92	66.2	66.64	69.45	77.2
DO Sat (%)	19	96	97.05	99.1	99.44	100.7	108.5
DRP (g/m^3)	20	0.002	0.003	0.0036	0.00415	0.005	0.0071
E coli (g/m^3)	21	80	140	360	559.5	545	3200
N total (g/m^3)	20	0.1075	0.185	0.2705	0.2829	0.3245	0.5283
Nitrate nitrate (as N) (g/m^3)	20	0.0582	0.129	0.2135	0.2244	0.2813	0.443
O_2 (g/m^3)	19	8.67	9.105	9.77	9.704	10.235	10.96
Total P (g/m^3)	20	0.0037	0.00585	0.01	0.00956	0.013	0.0183
pH	8	6.98	7.065	7.1	7.112	7.185	7.24
Total suspended solids (g/m^3)	8	0	0.2528	0.5	0.6601	0.5667	2.7143
Turbidity (NTU)	8	0.306	0.4427	0.6070	0.8794	0.6715	3.25
Water Temperature (°C)	19	10.7	15.05	16.6	16.65	18.5	21.7
Water Clarity (m)	8	1.408	5.069	5.684	5.384	6.56	7.499

State of the site

Microbiological guidelines assessment

Table B-17 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-17. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	490	5	6	5
Winter	4	110	4	0	0
All samples	20	360	9	6	5

Quarry Creek upstream of Boyd Tributary Confluence

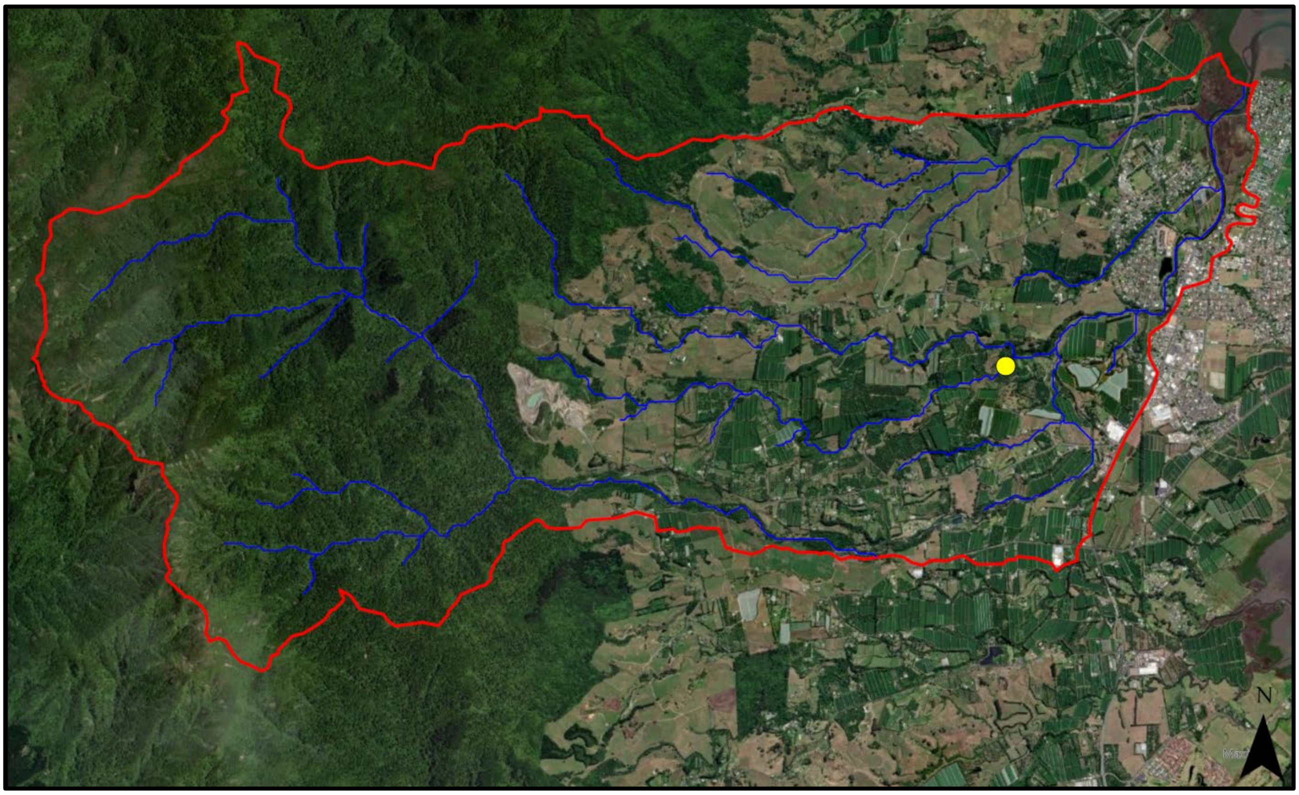

Figure B-9. Location of monitoring site in Quarry Creek upstream of Boyd Tributary confluence

Summary statistics

Table B-18. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	12	0	0.00175	0.0025	0.00317	0.004	0.007
Conductivity (us/cm)	0	-*	-	-	-	-	-
DO Sat (%)	11	98.1	99.75	101.5	101.32	102.9	104
DRP (g/m^3)	12	0.002	0.00375	0.004	0.00417	0.005	0.007
E coli (g/m^3)	12	100	2775	575	922.5	977.5	3800
N total (g/m^3)	12	0.376	0.439	0.5175	0.6315	0.6967	1.3530
Nitrate nitrate (as N) (g/m^3)	12	0.336	0.4088	0.4740	0.5845	0.6328	1.285
O_2 (g/m^3)	11	8.85	9.41	9.63	9.586	9.85	10
Total P (g/m^3)	12	0.008	0.011	0.0135	0.01408	0.0165	0.023
pH	0	-	-	-	-	-	-
Total suspended solids (g/m^3)	0	-	-	-	-	-	-
Turbidity (NTU)	0	-	-	-	-	-	-
Water Temperature (°C)	11	15.8	17.1	17.9	17.98	18.7	20.5
Water Clarity (m)	0	-	-	-	-	-	-

*Was not recorded at this monitoring site

State of the site

Microbiological guidelines assessment

Table B-19 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-19. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	12	575	3	2	7
Winter	0	NA	NA	NA	NA
All samples	12	575	3	2	7

Boyd Tributary upstream of Uretara Confluence

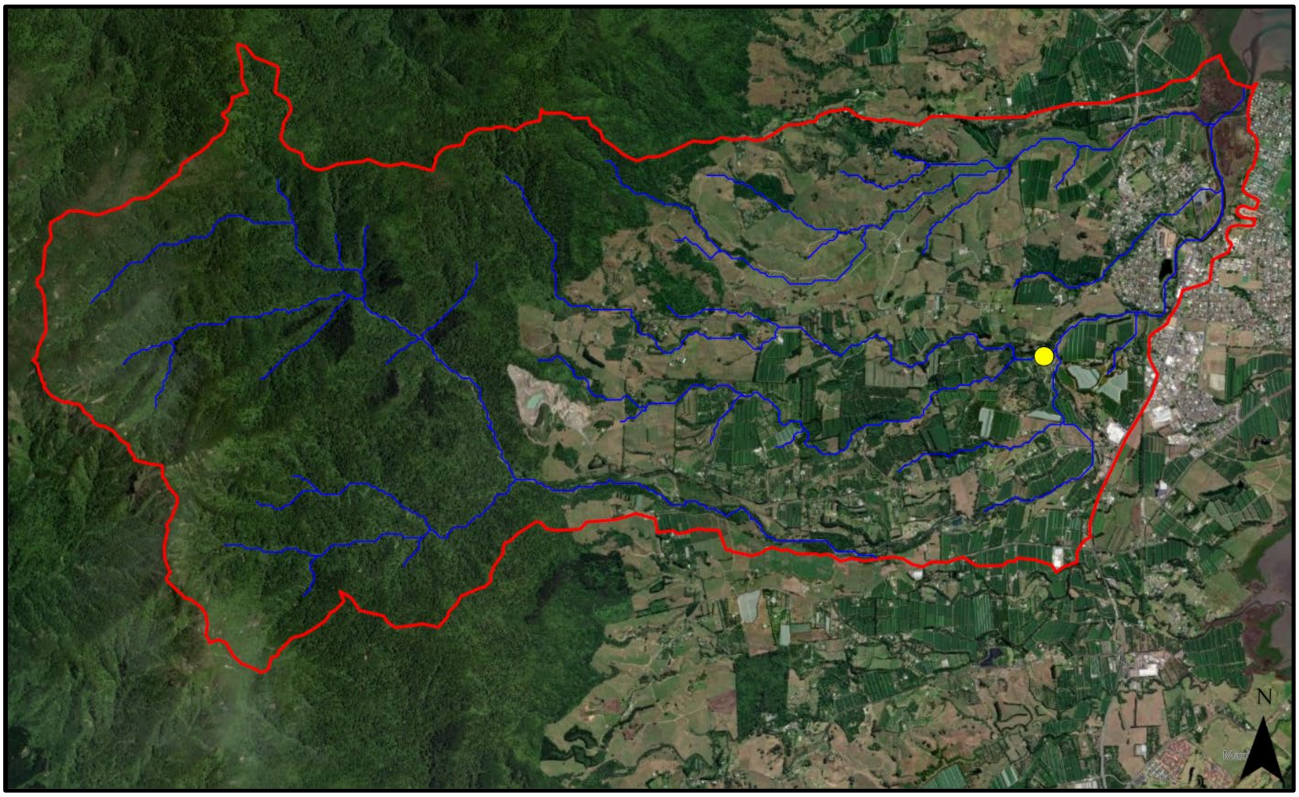

Figure B-10. Location of monitoring site in Boyd Tributary upstream of Uretara confluence

Summary statistics

Table B-20. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0.002	0.003	0.0061	0.00577	0.00735	0.011
Conductivity (us/cm)	8	62.3	66.65	72.25	70.55	73.33	78.3
DO Sat (%)	19	88.1	96.25	98	99.18	98.85	129
DRP (g/m³)	20	0.002	0.00248	0.0035	0.00400	0.00525	0.007
E coli (g/m³)	21	100	247.5	405	665	807.5	4000
N total (g/m³)	20	0.1539	0.2915	0.393	0.4235	0.5262	0.721
Nitrate nitrate (as N) (g/m³)	20	0.1001	0.2372	0.3357	0.3556	0.4364	0.641
O_2 (g/m³)	19	7.7	9.135	9.7	9.689	10.28	12.1
Total P (g/m³)	20	0.0036	0.0073	0.01	0.01131	0.01425	0.0251
pH	8	6.8	6.935	6.99	7.045	7.04	7.66
Total suspended solids (g/m³)	8	0.5556	0.6917	1.0389	1.375	1.4167	4
Turbidity (NTU)	8	0.636	0.7472	1.0195	1.6113	2.2	4.31
Water Temperature (°C)	19	10.4	14.6	16.5	16.54	18.4	21.6
Water Clarity (m)	8	1.045	3.309	3.928	3.994	4.985	6.241

State of the site

Microbiological guidelines assessment

Table B-21 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-21. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	545	4	4	8
Winter	4	215	2	2	0
All samples	20	405	6	6	8

Wharawhara Road Tributary upstream of Uretara Confluence

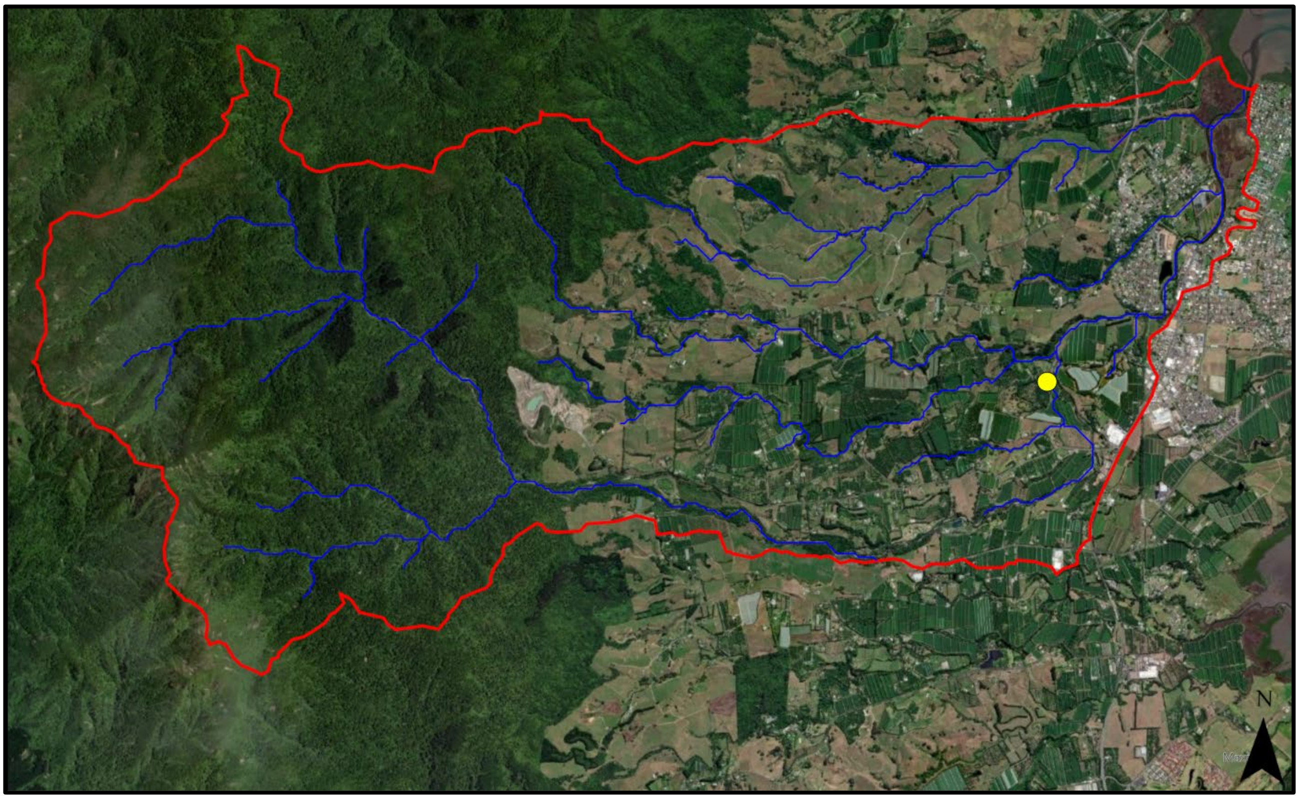

Figure B-11. Location of monitoring site in Wharawhara Road Tributary upstream of Uretara confluence

Summary statistics

Table B-22. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	20	0	0.00643	0.01085	0.01244	0.01725	0.039
Conductivity (us/cm)	8	83.4	88.6	94	91.94	95.05	96.9
DO Sat (%)	19	60.3	80	83.8	84.21	90	103
DRP (g/m^3)	20	0.001	0.00198	0.00305	0.0033	0.005	0.006
E coli (g/m^3)	20	55	90	250	486.4	472.5	4500
N total (g/m^3)	20	0.188	0.4105	0.5295	0.5805	0.7544	1.166
Nitrate nitrate (as N) (g/m^3)	20	0.07	0.2865	0.4695	0.488	0.6672	1.107
O_2 (g/m^3)	19	5.49	7.42	7.83	8.153	9.08	9.77
Total P (g/m^3)	20	0.0019	0.00635	0.01135	0.01034	0.01225	0.025
pH	8	6.5	6.527	6.575	6.741	6.69	7.71
Total suspended solids (g/m^3)	8	0.2	0.2167	0.3889	0.8972	1.8333	2
Turbidity (NTU)	8	0.257	0.3058	0.447	0.8652	1.0725	2.68
Water Temperature (^{o}C)	19	11.3	15.2	17.6	17.16	19.15	21.7
Water Clarity (m)	8	2.168	4.409	4.462	5.140	6.776	7.543

State of the site

Microbiological guidelines assessment

Table B-23 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-23. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	325	8	5	3
Winter	4	67	3	1	0
All samples	20	250	11	6	3

Uretara upstream of Wharawhara Road Tributary

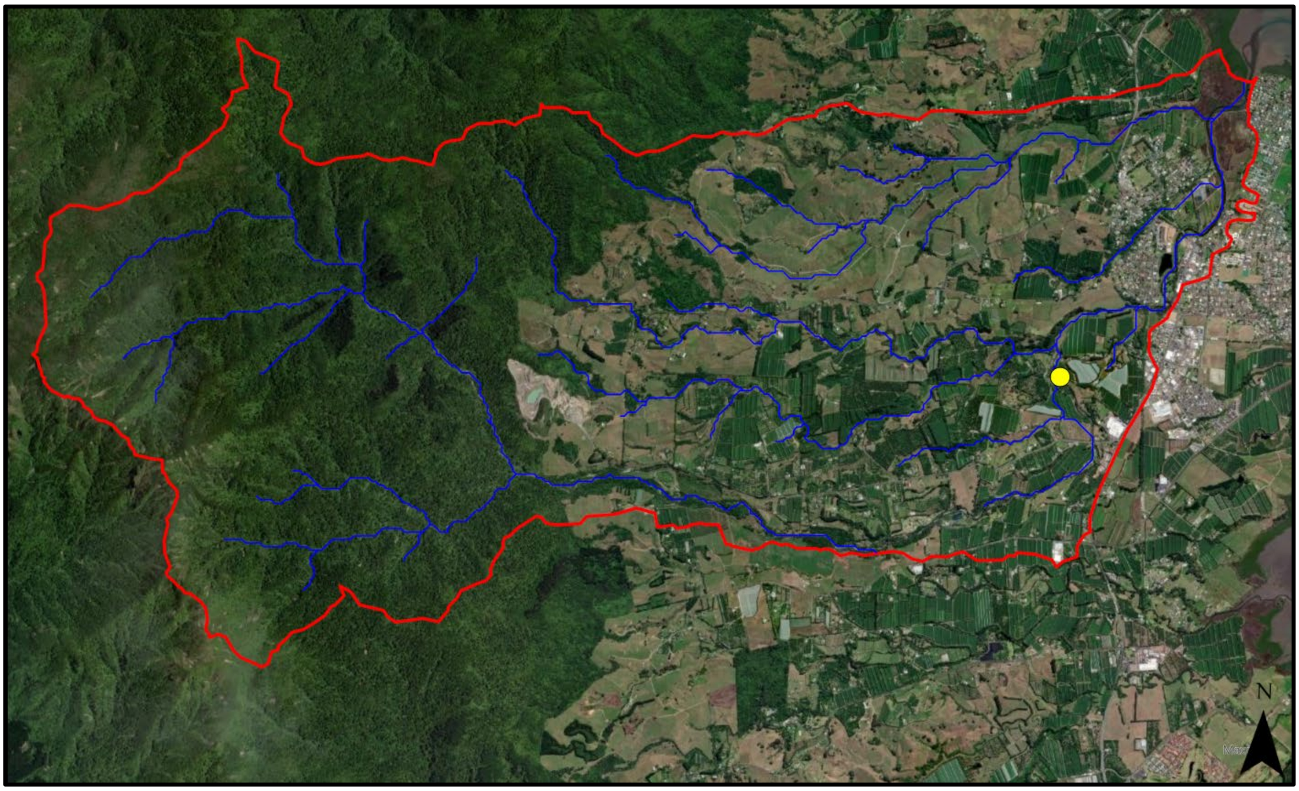

Figure B-12. Location of monitoring site in Uretara upstream of Wharawhara Road Tributary

Summary statistics

Table B-24. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0	0.00183	0.0035	0.00313	0.00485	0.0059
Conductivity (us/cm)	8	62.4	65.22	67.5	68.1	71.92	73
DO Sat (%)	19	98.1	100.4	102.5	103	104.9	108.7
DRP (g/m³)	20	0.0012	0.002	0.003	0.00346	0.005	0.007
E coli (g/m³)	20	24	74.25	100	159.7	175	590
N total (g/m³)	20	0.044	0.0725	0.1281	0.1213	0.1656	0.2278
Nitrate nitrate (as N) (g/m³)	20	0.007	0.03925	0.07580	0.08231	0.11525	0.2224
O_2 (g/m³)	19	9.12	9.56	9.9	10.02	10.19	11.31
Total P (g/m³)	20	0.001	0.00263	0.007	0.00639	0.00925	0.012
pH	8	7.03	7.143	7.205	7.119	7.272	7.39
Total suspended solids (g/m³)	8	0	0	0.1667	0.3944	0.3917	3.6
Turbidity (NTU)	8	0.17	0.24	0.2865	1.1838	0.6348	6.82
Water Temperature (°C)	19	10.6	15.35	17	16.81	18.35	22.3
Water Clarity (m)	8	3.644	6.519	7.355	6.993	7.992	8.764

State of the site

Microbiological guidelines assessment

Table B-25 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-25. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	16	150	12	3	1
Winter	4	49	4	0	0
All samples	20	100	16	3	1

Uretara at above Boyd Tributary

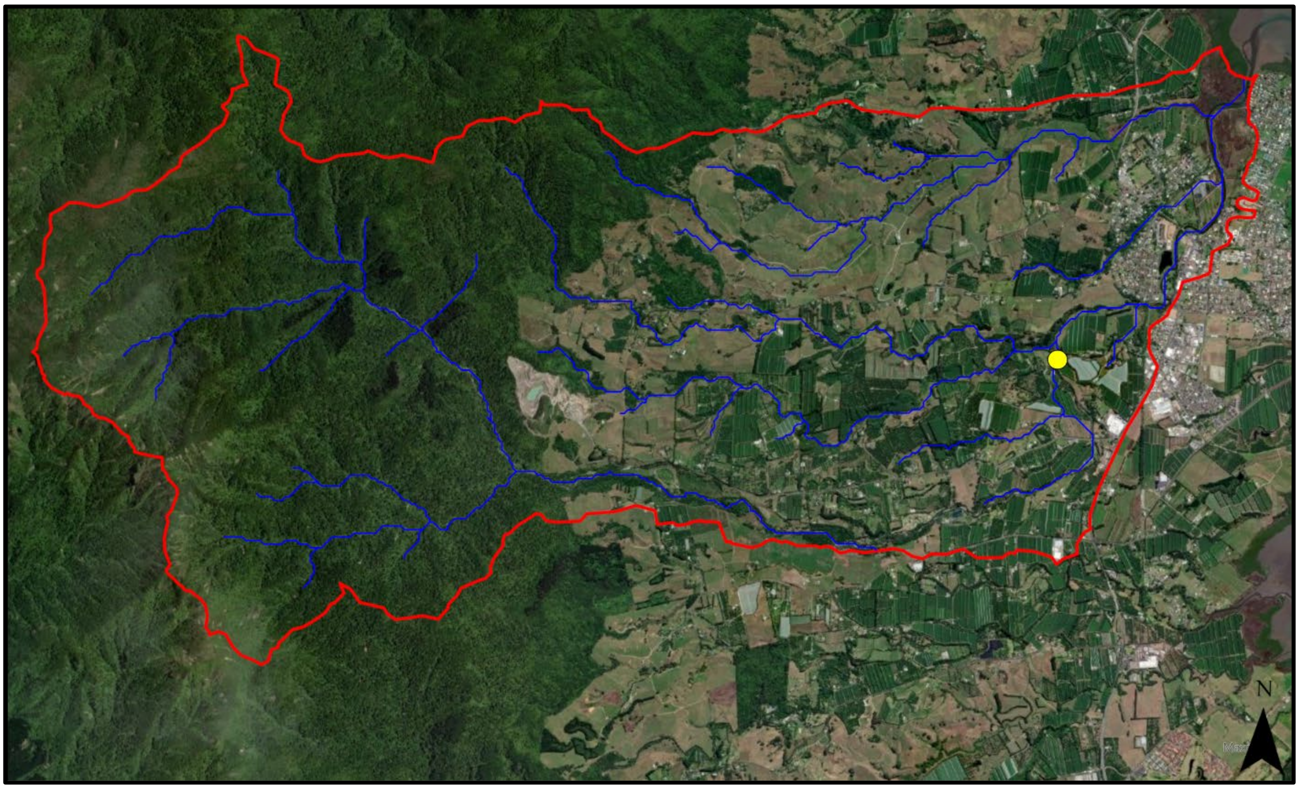

Figure B-13. Location of monitoring site in Uretara upstream of Boyd Tributary

Summary statistics

Table B-26. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m^3)	4	0.003	0.003	0.003	0.003	0.003	0.003
Conductivity (us/cm)	0	-	-	-	-	-	-
DO Sat (%)	3	106.0	107	108.1	110.6	112.9	117.7
DRP (g/m^3)	4	0.004	0.004	0.0045	0.0045	0.005	0.005
E coli (g/m^3)	5	17	38	47	68.4	100	140
N total (g/m^3)	4	0.072	0.093	0.1165	0.1098	0.1333	0.1340
Nitrate nitrate (as N) (g/m^3)	4	0.044	0.05975	0.067	0.06875	0.076	0.097
O_2 (g/m^3)	3	10.14	10.17	10.20	10.45	10.60	11
Total P (g/m^3)	4	0.008	0.008	0.0085	0.0085	0.009	0.009
pH	0	-	-	-	-	-	-
Total suspended solids (g/m^3)	0	-	-	-	-	-	-
Turbidity (NTU)	0	-	-	-	-	-	-
Water Temperature (°C)	3	17.1	17.85	18.6	18.23	18.8	19
Water Clarity (m)	0	-	-	-	-	-	-

State of the site

Microbiological guidelines assessment

Table B-27 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-27. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	5	47	5	0	0
Winter	0	NA	NA	NA	NA
All samples	5	47	5	0	0

Uretara at Henry Road Ford

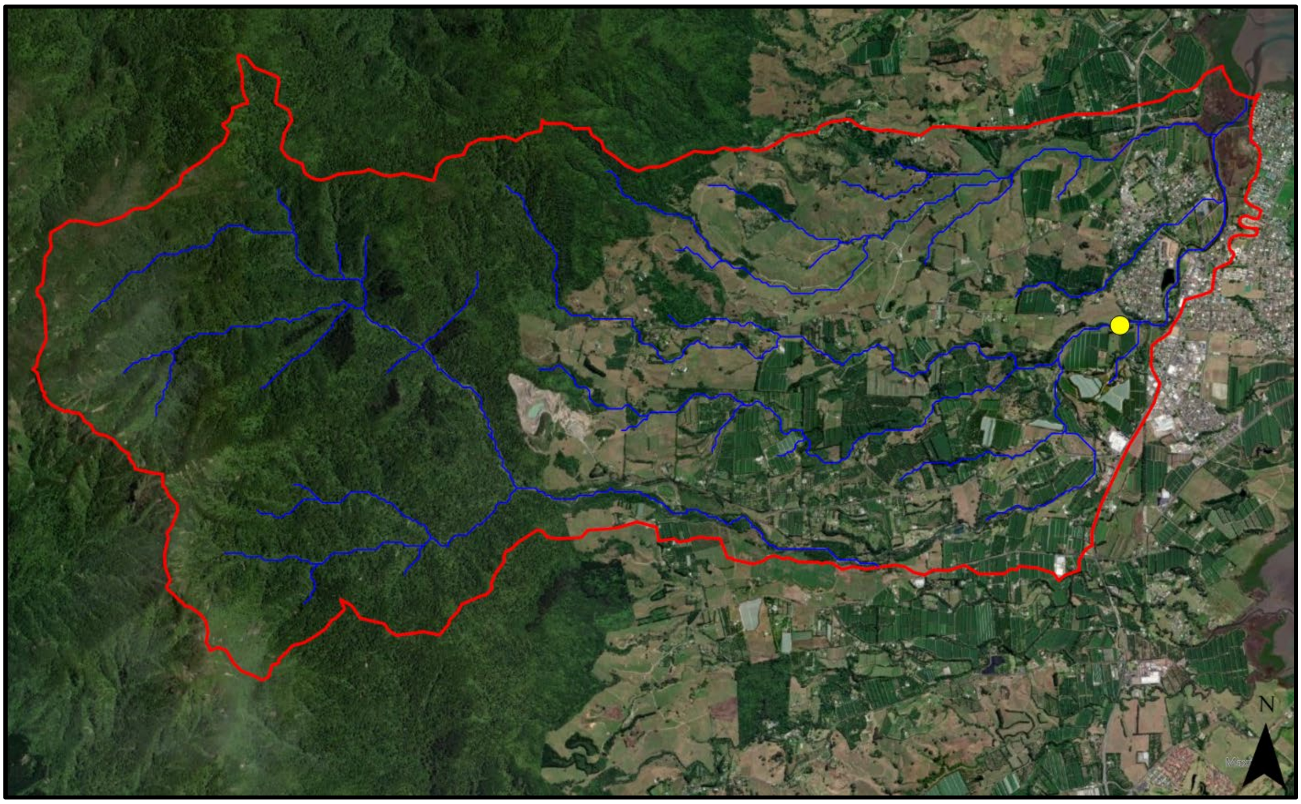

Figure B-14. Location of monitoring site in Uretara at Henry Road Ford

Summary statistics

Table B-28. Summary statistics calculated from all available data

Parameter	n	Min	1st quartile	Median	Mean	3rd Quartile	Max
Ammoniacal N (g/m³)	20	0.001	0.003	0.005	0.01187	0.0635	0.101
Conductivity (us/cm)	8	62.1	66.2	70.4	69.85	73.97	75.8
DO Sat (%)	20	67.4	94.55	99.05	96.17	101.55	105
DRP (g/m³)	20	0.0003	0.002	0.0044	0.00413	0.006	0.007
E coli (g/m³)	26	34	162	295	543	565	5100
N total (g/m³)	20	0.0696	0.1589	0.21	0.2149	0.2510	0.4260
Nitrate nitrate (as N) (g/m³)	20	0.0263	0.0815	0.1376	0.1573	0.2069	0.3760
O_2 (g/m³)	20	6.29	8.99	9.55	9.339	9.97	11.07
Total P (g/m³)	20	0.0011	0.00415	0.01	0.00969	0.01350	0.021
pH	8	6.95	7.07	7.155	7.15	7.218	7.37
Total suspended solids (g/m³)	8	0.1111	0.4167	0.500	1.5208	2.0417	4.5556
Turbidity (NTU)	8	0.393	0.4858	0.6055	1.2632	0.7612	5.91
Water Temperature (°C)	20	10.5	15.22	17.1	17.09	18.75	22.4
Water Clarity (m)	8	1.533	3.741	4.911	4.599	5.592	7.166

State of the site

Comparison Plots

The figures below compare median values for eight different measurements collected at the Uretara at Henry Road Ford site, against the distribution of data from all sites in the Bay of Plenty Region. The black dot represents the site's percentile score, with 0% equalling worst, and 100% equalling best. Each coloured segment represents 25% of the overall distribution. The segment colour scheme ranges from red (worst 25% of sites) to blue (best 25% of sites).

Based on the comparison plot presented below, the Henry Road Ford site is within the best 25% of sites in the Bay of Plenty region for most parameters. It is in the best 50% of sites for NNN, and the worst 50% of sites for *E. coli*.

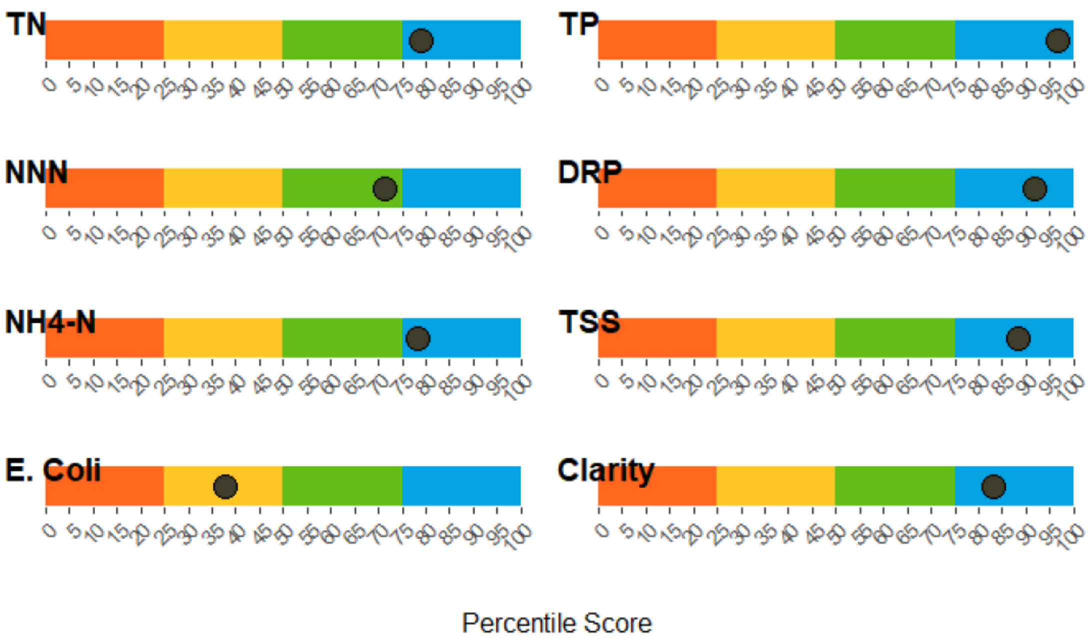

Figure 4-15. Comparison of the monitoring site in Uretara Stream at Henry Road Ford against other monitoring sites across the Bay of Plenty.

Microbiological guidelines assessment

Table B-29 contains the *E. coli* data assessed against the 'Surveillance, alert, and action level' framework for freshwater, from the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (2003). This framework is designed to inform the public of the bathing risk at a particular site, based on the results of a single water quality sample. This framework is utilised in the table below to indicate the extent of faecal contamination that may pose a risk to human health.

Data is summarised by season, with winter being all months between June and October (inclusive), and summer being all months between November and May (inclusive). The overall number of samples that fit into each category, for each period, are calculated on the right of the table.

Table B-29. MWQG levels for freshwater

Period	n	Median (cfu/100 mL)	Green	Amber	Red
Summer	22	335	7	8	7
Winter	4	155	4	0	0
All samples	26	295	11	8	7

5 Summary of Recommendations

It appears that both catchments are affected by contributions in the upper catchment above where the monitoring programme has enumerated E. coli (and other analytes). Therefore, it would be beneficial to complete a survey or monitoring in the upper catchment to better target locations for management and/or mitigation.

5.1 Ngongotahā Catchment

Recommendations for further assessment are as follows:

The Ngongotahā Stream conveys greater *E. coli* loads compared to the other streams and tributaries that join with it. It does appear that water quality is already affected at the upper monitoring sites, which suggests that lowland activities are not the primary source, or primary area to be targeted by mitigation strategies.

Recommendations for further assessment are as follows:

i. **Continue monitoring to assess whether the piggery closure has had an effect on catchment water quality.**

   A pig farm that was allowing effluent to directly enter the Ngongotaha network was closed, which may affect the recommendations of the present results. The effects of closing the piggery on water quality has not been quantified, as monitoring concluded prior to its closure.

ii. **Establish monitoring sites on the western perimeter of the Ngongotahā catchment to provide greater resolution of potential *E. coli* sources**

   The monitoring data indicates that the source of *E. coli* loading is in the upper reaches of the Ngongotahā catchment, affecting the Ngongotahā Stream and Ohinenui Stream prior to monitoring sites. It is recommended that monitoring occurs in the upper reaches of the Ohinenui Stream and Ngongotahā Stream. In doing so, the effects of the upslope agricultural activities may be isolated and identified.

iii. **Provide education and services to encourage the protection of waterways (e.g. fencing, stock exclusion, bridges), and continue monitoring to assess whether introducing these measures / inhibiting direct deposition into waterways reduces *E. coli* loads during the summer period.**

   Currently, there is a greater percentage of sample events in the allocated summer period that exceed Amber or Red *E. coli* thresholds, and there are very few sample events in the winter period that exceed these thresholds. This may be due to the effects of dilution in winter, or may indicate that direct deposition of faecal matter is occurring within waterways. By encouraging stock exclusion from waterways, future *E. coli* monitoring can be used to assess whether direct deposition was a primary contributor, or whether diffuse sources are still contributing significant *E. coli* loads during summer.

iv. **Assess the activities at / upstream of the Paradise Valley wildlife park**

   The Ngongotahā Stream monitoring site at Paradise Valley is located downstream of a wildlife park with grazing animals and a waterfowl wetland. Viewing/assessing the site and its activities may be beneficial to identify potential sources of faecal contamination in the waterway (e.g. waterfowl nesting areas, the sheep facilities).

v. **Establish a monitoring site upstream of the Paradise Valley wildlife park**

If the site walkover of the park and activities is inconclusive, it may be necessary to establish the monitoring site for *E. coli* concentration and FST upstream of the wildlife park, to eliminate the potential effects of the park on results.

vi. **Explore a more bespoke public health risk model for the Ngongotaha catchment and wider Rotorua area.**

With the existing *E. coli* database, it may be beneficial to investigate a bespoke Quantitative Microbial Risk Assessment (QMRA) for the relative health risk posed by *E. coli* exposure at swimming sites. Currently, a generalised public health system assessment is utilised in the Rotorua region to assess swimmability and safety. However, it may be beneficial to use the data collected establish a relative target for the swimming sites that, on balance, is achievable and low risk to the public.

5.2 Uretara Catchment

Overall, the catchment would benefit from ongoing monitoring and engagement to improve water quality.

i. **Create and refine synthetic flow equations for the other sites in the catchment, to allow for load calculations across the catchment. Alternatively, consider other approaches to estimating flow rates within the catchment.**

Refining flow measurement would mainly be of benefit to determine relative loads once the primary source of *E. coli* is established. A potential method would be to estimate the ratio of smaller streams to gauged sites, and crudely calibrate a flow model for the catchment. Alternatively, a proportional approach could be used, in line with the work done in the Ngongotahā catchment.

However, this is not considered a key action at this stage of data collection.

ii. **Investigate *E. coli* sources within the indigenous forest upstream of the Boyd Tributary, Peach's Creek and Quarry Creek, and potential avian sources in the lowland areas.**

Carry out a site walkover of the upper reaches of the creeks and tributary, to assess whether there are any established colonies or evidence of wildlife that are contributing to *E. coli* loads in the indigenous forest. The wetland upstream of Peach's Creek monitoring site should be investigated.

There are indications of an avian faecal source, particularly in the lower monitoring area at Henry Road Ford. Additional lowland surveys may be beneficial. However, previous initiatives (i.e. goose colony culling and manure management) does not appear to have a conclusive influence.

iii. **Further investigation into *E. coli* sources in the Uretara catchment.**

It may be prudent to conduct a specific programme for FST data in the Uretara catchment. Based on the FST data presented, many samples do not provide any conclusive source of faecal contamination or can only account for a small percentage of the source. Having a stronger understanding of the source may improve the ability to create a targeted mitigation strategy. One method would be to filter a larger volume of water to increase the amount of sample to analyse.

iv. **Specifically, investigate *E. coli* sources in the farmland upstream of the Peach's Creek, Boyd Tributary, Boyd Creek and Quarry Creek sites, and support Land Management Officers to engage with the community/land managers to explore water quality measures.**

As ruminant sources have been identified, mitigation measures in the farmland between the forest and the first monitoring sites should be investigated and encouraged. These include:

- Riparian planting,
- Creating exclusion zones, fencing, and reducing the number of stock crossings in streams,

- Introducing and encouraging best practice around farm dairy effluent management and discharge to waterways

Additionally, current *E. coli* results show that *E. coli* concentrations in the summer periods are greater than in the winter periods. This is either due to the effects of dilution, or may suggest that direct deposition of faecal matter into waterways is occurring. By encouraging and instigating stock exclusion measures, further monitoring may be able to identify whether this was a primary source of *E. coli* loads during the summer months.

v. Investigate mitigation measures between the Quarry on Wharawhara Road and Peach's Creek/Quarry Creek

The median sediment load into Peach's Creek and Quarry Creek is the greatest in the catchment. They are adjacent to an active quarry, and may be negatively affected by the soil disturbance activities occurring. An investigation should be carried out to identify potential sediment loss pathways, and sediment mitigation measures should be explored between the Quarry and creeks.

6 References

Beyá, J., Hamilton, D. & Burger, D. (2005). Analysis of catchment hydrology and nutrient loads for Lakes Rotorua and Rotoiti. Centre for Biodiversity and Ecology Research, University of Waikato.

BOPRC. (2012). *Uretara: Sub-catchment Action Plan 2012.* Bay of Plenty Regional Council Environmental Publication 2012/09.

BOPRC. (2020). *Uretara Catchment*. Retrieved from https://www.boprc.govt.nz/our-projects/uretara-catchment#:~:text=About%20the%20Catchment,being%20exotic%20forest%20and%20urban.

BOPRC. (2022, February 2). *Pig farm prosecution shows importance of correcting farming practices.* BOPRC Media Release 2022. Retrieved from https://www.boprc.govt.nz/your-council/news/news-and-media-releases/media-releases-2022/february-2022/pig-farm-prosecution-shows-importance-of-correct-farming-practices.

Carter, R., Suren, A. & Scholes, P. (2017). *Water quality and ecological attributes for rivers and lakes in the Bay of Plenty: Report 1.* Bay of Plenty Regional Council Environmental Publication 2017/06.

Dare, J. (October 2020). Recreational Waters Surveillance Report. BOPRC, Whakatāne.

Environment Court New Zealand (2022). Enforcement Orders (NZENVC 003 ENV-2022-AKL-000009 & NZDC 1128 CRI-2021-063-001521). Retrieved from https://www.justice.govt.nz/assets/2022-NZEnvC-003-Bay-of-Plenty-Regional-Council-v-Kleadmak-Farms-Limited.pdf

Griffiths, E. (2022, January 25). *Rotorua company fined $27K for allowing pig effluent, carcasses to flow into Lake Rotorua.* New Zealand Herald. Retrieved from https://www.nzherald.co.nz/nz/rotorua-company-fined-27k-for-allowing-pig-effluent-carcasses-to-flow-into-lake-rotorua/JHHYCDJAJXZPXM6RXPZMPDZ2TE/

Mahon, L., Zygaldo, M., Carter, R., Crawshaw, J. & Dare, J. (2020). *Focus Catchments Water Quality 2020/Te kounga Wai O Ngā Kurawai E Arotahia Ana.* Bay of Plenty Regional Council Environmental Publication 2020/04.

MfE, 2021. *National Environmental Indicators*. Retrieved from https://environment.govt.nz/publications/environment-new-zealand-2007/chapter-10-freshwater/national-environmental-indicators/#:~:text=(Low%20elevation%20streams%20and%20rivers,in%20the%20peak%20of%20summer.). Accessed on 9 November 2022.

MfE, 2020. *National Policy Statement for Freshwater Management 2020*. Ministry for the Environment Publication ME 1718.

NZLRI Land Use Capability 2021 – LRIS Portal, 2021. Retrieved from https://lris.scinfo.org.nz/search/?q=land+use. Accessed on 8 November 2022.

Whitehead, A., Depree, C. & Quinn, J. (2019). *Seasonal and Temporal Variation in Water Quality in New Zealand Rivers and Lakes (Report No. 2019024CH).* Prepared for the Ministry for the Environment.

Wilcock, B. (2006). Assessing the Relative Importance of Faecal Pollution Sources in Rural Catchments (NIWA Client Report HAM2006-104). NIWA: Hamilton, New Zealand.