Technical Report

MOTUEKA / RIWAKA PLAINS GROUNDWATER QUALITY SURVEY 2019




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October 2020

A technical report presenting results of the Tasman District Council's groundwater quality synoptic survey undertaken in the Motueka / Riwaka Plains. The report draws on various monitoring data collected by Tasman District Council, including that collected for the Institute of Geological and Nuclear Sciences Ltd as part of the National Groundwater Monitoring Programme and the Institute of Environmental Science and Research as part of the national survey of pesticides, glyphosate and emerging organic contaminants.

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EXECUTIVE SUMMARY

This report presents the results of the 2019 groundwater quality synoptic survey in the Motueka / Riwaka Plains. The purpose of the survey was to identify any health risks to the groundwater users, to describe the current groundwater quality status in the Motueka / Riwaka Plains and to assess any changes from previous groundwater quality synoptic surveys. The Health Act 1956, Section 69U, also requires Councils to take reasonable steps to contribute to the protection of source drinking water.

Three plains-wide synoptic groundwater quality surveys in the Motueka / Riwaka Plains have previously been undertaken in 1990, 2003 and 2010/2011. This report presents the results of the fourth and most recent plains-wide survey of groundwater quality. The 2019 survey sampled groundwater from 184 bores and 10 river/spring sites across the Motueka / Riwaka Plains during October and November 2019. In addition, Council monitors four groundwater sites in the Motueka / Riwaka Plains as part of the long term State of the Environment monitoring programme. Council also participates in the national pesticide surveys conducted by the Institute of Environmental Science Research (ESR) in selected bores across the region, including in the Motueka / Riwaka Plains. This data has been incorporated into this report.

With regards to water chemistry, the 2019 Motueka / Riwaka Plains survey found the groundwater to be of good quality. The majority of the health significant and aesthetic parameters from the Drinking Water Standards for New Zealand 2005 (Revised 2018) (DWSNZ) in the bores tested were of concentrations well below the maximum acceptable and guideline values. The water quality of the Motueka and Riuwaka Rivers, which are the main sources of recharge for the aquifer, are also of good quality.

Groundwater quality has remained consistently good when compared with the previous synoptic surveys, with no significant changes to the majority of water chemistry parameters. Despite the widespread agricultural and horticultural activities on the Plains, nitrate concentrations are low, with the majority of bores sampled under 50% of the maximum acceptable value in the DWSNZ.

All pesticides residues detected by ESR in 2018 were well below the maximum acceptable values in the DWSNZ. Two bores in the Motueka / Riwaka Plains had detections of emerging organic contaminants (EOC) from the 2018 survey which are being followed up on accordingly. None of the selected bores in the Tasman region had glyphosate detected.

Due to its unconfined/semiconfined (leaky) nature, the aquifer underlying the Motueka / Riwaka Plains, it does not meet the DWSNZ definition for secure groundwater. The 2019 survey identified various risks to the security of the groundwater quality in the Motueka / Riwaka Plains. These risks included:

- Well/boreheads next to rubbish storage, stormwater drains and in low-lying areas
- Chemical storage in the vicinity of well/boreheads
- Historic driven pipes not sealed at ground level or appropriately sealed
- Wells with unsealed well liners and inadequately fitting lids
- Lack of records on individual bore supplies due to them being a permitted activity

Council is currently in the process of considering whether all of Councils current water supplies should be permanently chlorinated. This is in response to what could be required in the new water services bill. This will have impacts on the current Council Motueka and Kaiteriteri/Riwaka Plains reticulated water supplies.

In order to manage the risk of contamination to the aquifer underlying the Motueka / Riwaka Plains, there are the following recommendations:

- Increase awareness of private bore owners on how to reduce their risk of bore contamination. Relevant information will be provided on the Council website and via the Newsline magazine.
- Increase awareness for bore drillers and non-Council water service agents (private and community) on the importance of borehead security and the need to improve this. Education/training for Council Environmental Health Officers by appropriate qualified Drinking Water Assessors to be provided to address borehead security.
- Council continues to be involved in the ESR pesticide, glyphosate and EOCs survey in the future.
- Council includes sampling for *Escherichia coli* (a faecal indicator bacteria) and total coliforms as part of the State of the Environment groundwater monitoring programme. These parameter can provide an early indication of bacterial contamination in the aquifer and near the bore.
- Council considers the need for full reticulation of the area because of the potential contamination risk to the shallow bores.

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LIST OF ABBREVIATIONS

Council	Tasman District Council
DWSNZ	Drinking Water Standards for New Zealand 2005 (Revised 2018)
E. coli	*Escherichia coli* (a faecal indicator bacteria)
EHO	Environmental Health Officer
EOC	Emerging Organic Contaminant
ESR	Environmental Science and Research Ltd
FCP	Food Control Plan
GV	Guideline Value
MAV	Maximum Acceptable Value
NPSFM	National Policy Statement for Freshwater Management 2014 (Revised 2020)
SoE	State of the Environment
TLA	Territorial Local Authorities
TRMP	Tasman Resource Management Plan
UV	Ultra Violet

STATEMENT OF DATA VERIFICATION AND LIABILITY

Tasman District Council recognises the importance of good quality data. This assessment of groundwater quality across the Motueka / Riwaka Plains aquifer system provides interpretation of results from the Council's groundwater quality monitoring programme and other relevant data available at time of producing the report. Data collection and management systems follow systematic quality control procedures. International Accreditation New Zealand (IANZ) laboratories carried out sample analysis excluding field analysis.

While every attempt has been made to ensure the accuracy of the data and information presented, Tasman District Council does not accept any liability for the accuracy of the information. It is the responsibility of the user to ensure the appropriate use of any data or information from the text, tables or figures. Not all available data or information is presented in the report. Only information considered reliable, of good quality and of most importance to the readers has been included. All tables and figures have been created by the authors unless otherwise stated.

1 Introduction

1.1 Background

The Motueka / Riwaka Plains covers approximately 40 km^2. The aquifer underlying the Motueka / Riwaka Plains is unconfined with the permeable water bearing strata open to the ground surface. The aquifer is bounded in the west, north and base by faulted granite rock and in the south by older, low permeability Moutere gravels. A cross section of the Motueka / Riwaka Plains aquifer system can be seen in Figure 1. The lithology (physical characteristics of rocks in a particular area) and thickness of the aquifer layers vary across the plains.

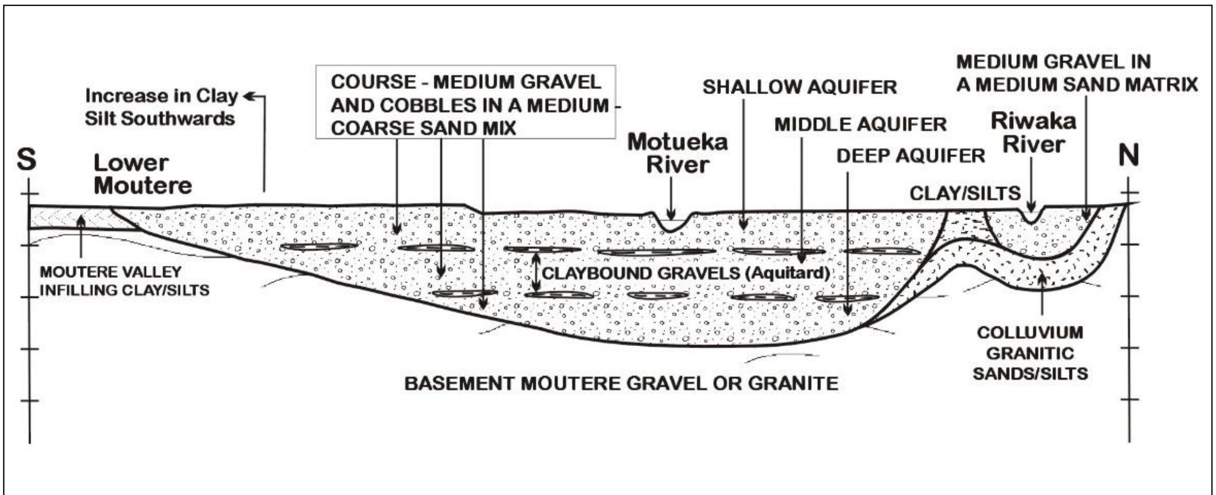


Figure 1: North-south cross section of the Motueka / Riwaka Plains aquifer system. Reproduced from Robb (1999), originally generated by Thomas (Tasman District Council).

The thickness of the alluvial gravels in the central area of the plains is approximately 20 to 30 m. This reduces to about 6 m towards the fringes. To the south, the gravels are mixed with material flushed out of the Moutere Valley and have a high content of fine sands, silts and clays. In the central part of the plains the gravels are freer, consisting of well-rounded clasts predominantly of granite, sandstone, siltstone and basic igneous rock. Towards the Riuwaka River, the gravels are reworked by the river and are mixed with colluvial granite deposits.

Unconfined/semiconfined (leaky) aquifers are recharged through surface water interactions (rivers/streams can gain or lose water to the underlying aquifers depending on the groundwater level) and rainfall soaking though the overlying soil layers. Land use occurring above an unconfined aquifer can also directly influence the groundwater quality.

The Motueka River provides considerable recharge to the Motueka / Riwaka Plains aquifer system, with groundwater flowing generally to the southeast (see Figure 2). To a more localised extent the Riuwaka River, Little Sydney and Brooklyn Streams also provide recharge in their vicinities. Groundwater closer to the rivers and streams is strongly influenced by the river water quality, particularly near the Motueka River. Groundwater increases with age away from the main recharge area (near the rivers) and the quality is more influenced by various overlying land activities and groundwater / rock interactions. Leaching of chemicals and nutrients added to the soil can enter into the groundwater as rain or irrigation soaks through the soil column. Groundwater exits the aquifer system by subsurface flow into Tasman Bay, into springs near the coast, into rivers or via groundwater pumping.

Approximately one-third of the houses in Motueka are connected to the Tasman District Council (Council) water supply. This makes Motueka the largest town in New Zealand that doesn't have a fully reticulated (networked) supply. There is an estimated 2,000 private domestic bore water takes in Motueka, used for both domestic and commercial/irrigational purposes. Local bores source water from the underground aquifer (water bearing layers) that underlies the Motueka / Riwaka Plains.

For household bores (where the water supply is used only by the people on that property) there is no requirement for the property owner to regularly test the water quality. Most of these household bores are 'pile driven' and shallow (4 - 6 m deep). Private bores in the Motueka / Riwaka Plains sometimes supply multiple houses, businesses, public facilities, community centres and schools. Due to the shallow nature of the majority of the private bores in the Motueka / Riwaka Plains there is a risk of contamination occurring in the aquifer from surrounding activities and the state of the bore head security.

Councils have responsibilities under the Health Act 1956, Section 69U duty to take reasonable steps to contribute to the protection of source of drinking water. By assessing the water quality and bore details of private bores in the Motueka / Riwaka Plains, provides a better understanding of the risks to groundwater from these bores and also the Council supply bores that abstract from the same aquifer. In the case of Council water supply bores it has a duty to monitor its source water for the Motueka and Kaiteriteri water supply bores and within the distribution network.

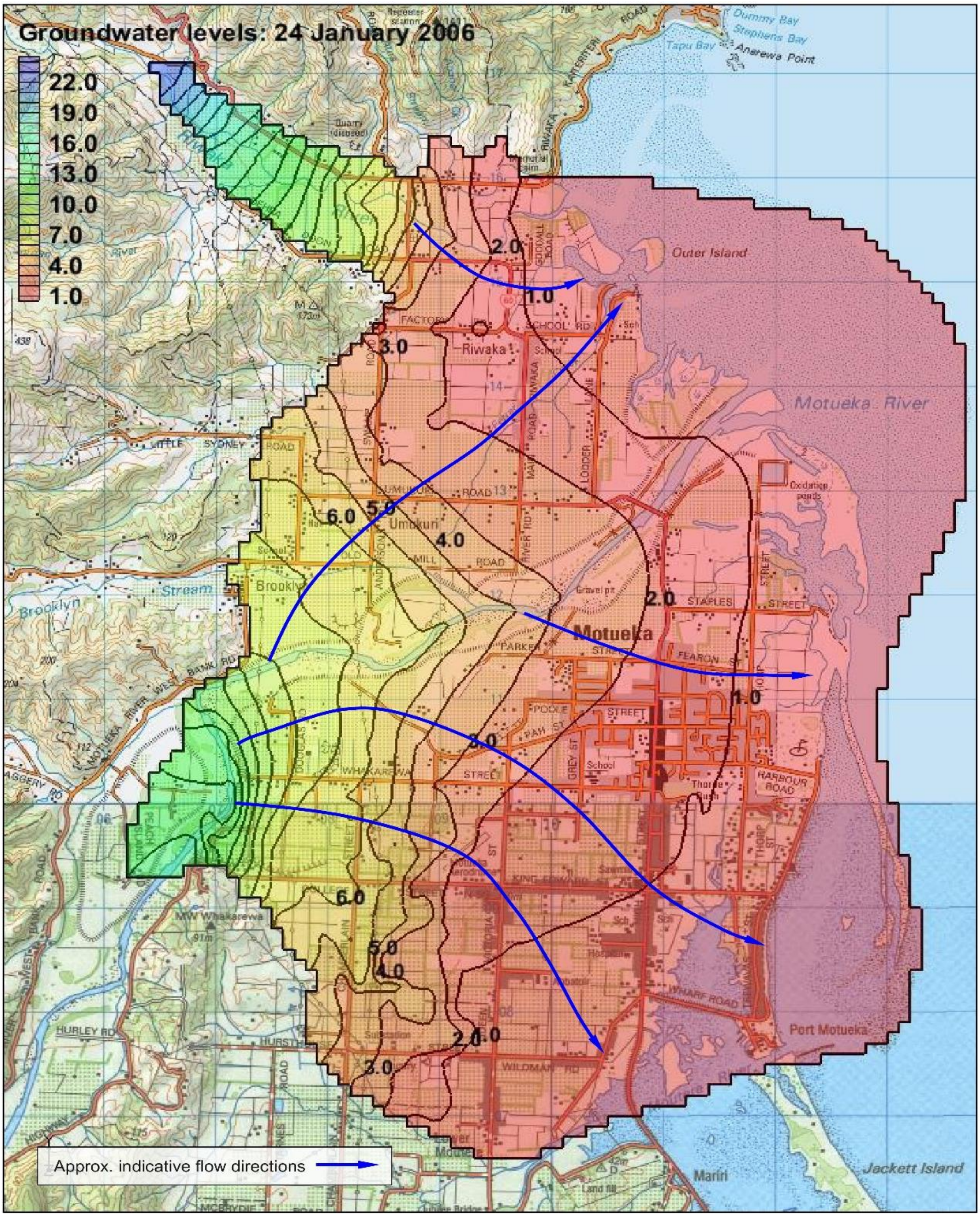


Figure 2: Modelled groundwater level contours and indicative flow direction. Reproduced from Weir and Thomas (2018).

1.2 Groundwater Quality Survey

In October and November 2019 a groundwater quality survey was undertaken in the Motueka / Riwaka Plains. 184 bores/wells spread across the Motueka / Riwaka Plains were sampled. 10 springs/rivers were also sampled to draw comparisons between the recharge river source, groundwater quality from the bores and groundwater quality from the springs. Figure 3 shows the location of the bores, springs and rivers which were sampled in the 2019 survey. Similar synoptic surveys (i.e. lots of sites sampled over a short time) were completed in 1990, 2003 and 2010/2011 in this area.

There were four suites of laboratory tests used for analysis: minor, major, stormwater/hydrocarbon and horticulture/agriculture (i.e. agrichemicals). The parameter tests conducted for each suite are detailed in Section 2. The 2019 survey conducted additional physical water chemistry parameter tests, alongside the parameters tested in the previous synoptic surveys in 1990, 2003 and 2010/2011. The results of the 2019 survey can now be compared to the water quality of the previous groundwater synoptic surveys and enable assessment of any changes over time including health risks to water users.

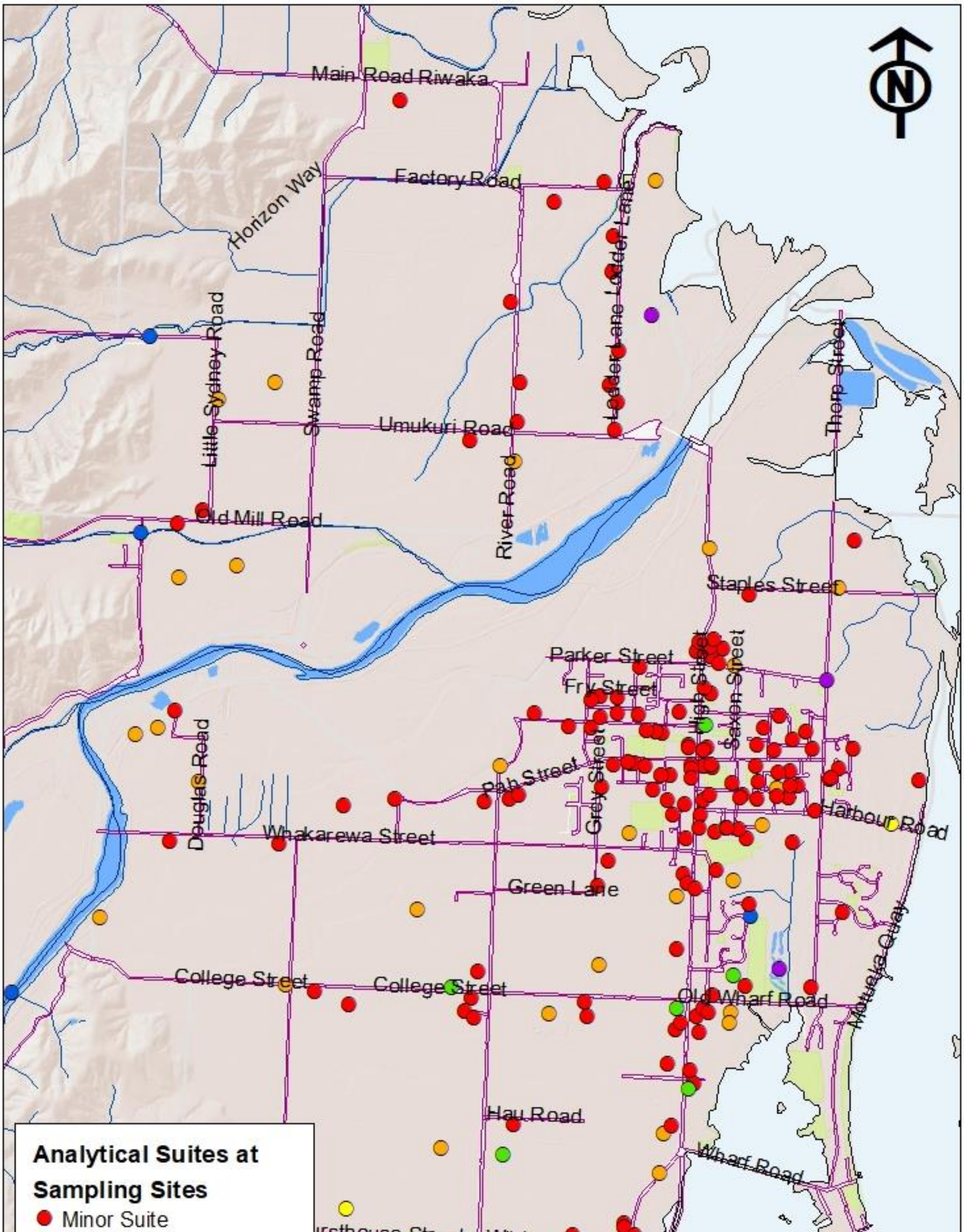


Figure 3: Location of all bores, springs and rivers sampled in the 2019 Motueka / Riwaka Plains groundwater survey.

2 Sampling Method

During the months of October and November 2019, 184 bores in the Motueka and Riwaka Plains were located and sampled. 147 had the water tested for the minor suite, 28 were tested for the major suite, 6 were tested for the stormwater/hydrocarbon suite and 3 were tested for the horticultural/agricultural suite. These suites were tested for the following parameters:

Minor suite (147 bores):

- Dissolved Calcium
- Dissolved Iron
- Dissolved Magnesium
- Dissolved Manganese
- Dissolved Reactive Phosphorus (trace)
- Free Carbon Dioxide
- Nitrite-N
- Nitrate-N
- Nitrite-N + Nitrate-N
- pH
- Total Alkalinity
- Total Ammoniacal-N Trace
- Total Coliforms and *E.coli*
- Total Hardness
- Turbidity

Major suite (28 bores) tested for all the minor suite parameters plus:

- Chloride
- Dissolved Antimony
- Dissolved Arsenic
- Dissolved Barium
- Dissolved Boron
- Dissolved Cadmium
- Dissolved Copper
- Dissolved Lead
- Dissolved Mercury
- Dissolved Nickel
- Dissolved Potassium
- Dissolved Selenium
- Dissolved Sodium
- Dissolved Zinc
- Sulphate

Stormwater/hydrocarbon suite (6 bores) tested for all the major suite parameters plus:

- Semivolatile Organic Compounds Trace in Water by GC-MS
- Volatile Organic Compounds Trace in Water by Headspace GC-MS

Horticultural/agricultural suite (3 bores) tested for all the major suite parameters plus:

- Acid Herbicides Screen in Water by LCMSMS
- Multiresidue Pesticides Trace in Water by Liq/liq GCMS

In addition, 10 springs/rivers sites were also tested for the major suite water analysis, with the Motueka and Riuwaka Rivers tested above the sampling areas to provide an indication of the water quality entering the aquifers.

Bores were selected from a combination of targeted sites and random selection from areas outside of the Council reticulated drinking water supply. Targeted sites included accommodation providers (backpackers, camp grounds, motels), commercial facilities (airports, factories, cool stores), community centres (churches, recreational facilities), education (schools, early childhood centres), food premises (cafes, restaurants), healthcare providers (retirement villages), irrigation (orchards, horticulture/agriculture facilities) and water schemes (Council water supplies and private community supplies). The remaining bores were private domestic households that were chosen randomly for spatial coverage across the plains. The distribution of bores showing water usage can be seen in Figure 4.

The testing endeavoured to replicate the 2010/2011 survey, with some additional bores added in 2019 for a more complete coverage of the region. Some of the bores tested in the 2010/2011 survey were no longer able to be tested. In this case, a nearby bore was selected to replace it in the survey to keep an even distribution around the sample area.

Each sample was taken directly from the sampling tap or pump outlet. The supply was left to run from either an existing pump or a portable pump, via a hose or directly onto the ground, for a minimum duration of five but preferentially up to ten minutes. The pH (using an ExTech PH10 meter), conductivity, dissolved oxygen and temperature (using a YSI Pro Plus meter) were measured by filling (and overflowing) a bucket so the probes received constant flow over the sensors.

After pumping, the sampling tap/outlet was cleaned using a paper towel sprayed with methylated spirits, followed by disinfection using flame (where possible). The tap/outlet was then run for a few seconds to allow any water impacted by the cleaning process to flush out. The bottles used for each sample suite is detailed in Appendix I. The water sample was filled directly into the bottles from the tap/outlet. Unpreserved bottles were filled directly to the top of the bottle. Preserved bottles were filled to 1 cm below the rim of the bottle so none of the preservative which coated the inside of the bottle was lost by overfilling or spilling.

The filled bottles were then labelled and bagged to keep all the bottles from each site together. Once bagged, the samples were placed in a chilly bin, kept cool with ice packs and couriered overnight to Hill Laboratories. Samples which required filtering for analysis were filtered by Hill Laboratories directly.

The river and spring samples were taken using a simple grab method, where the sample bottles and lid were dipped into the water until they were filled. The lid was screwed underwater to avoid any surface water scum entering the sample. The field measurements were taken by dipping the probes into the main flow of the water.

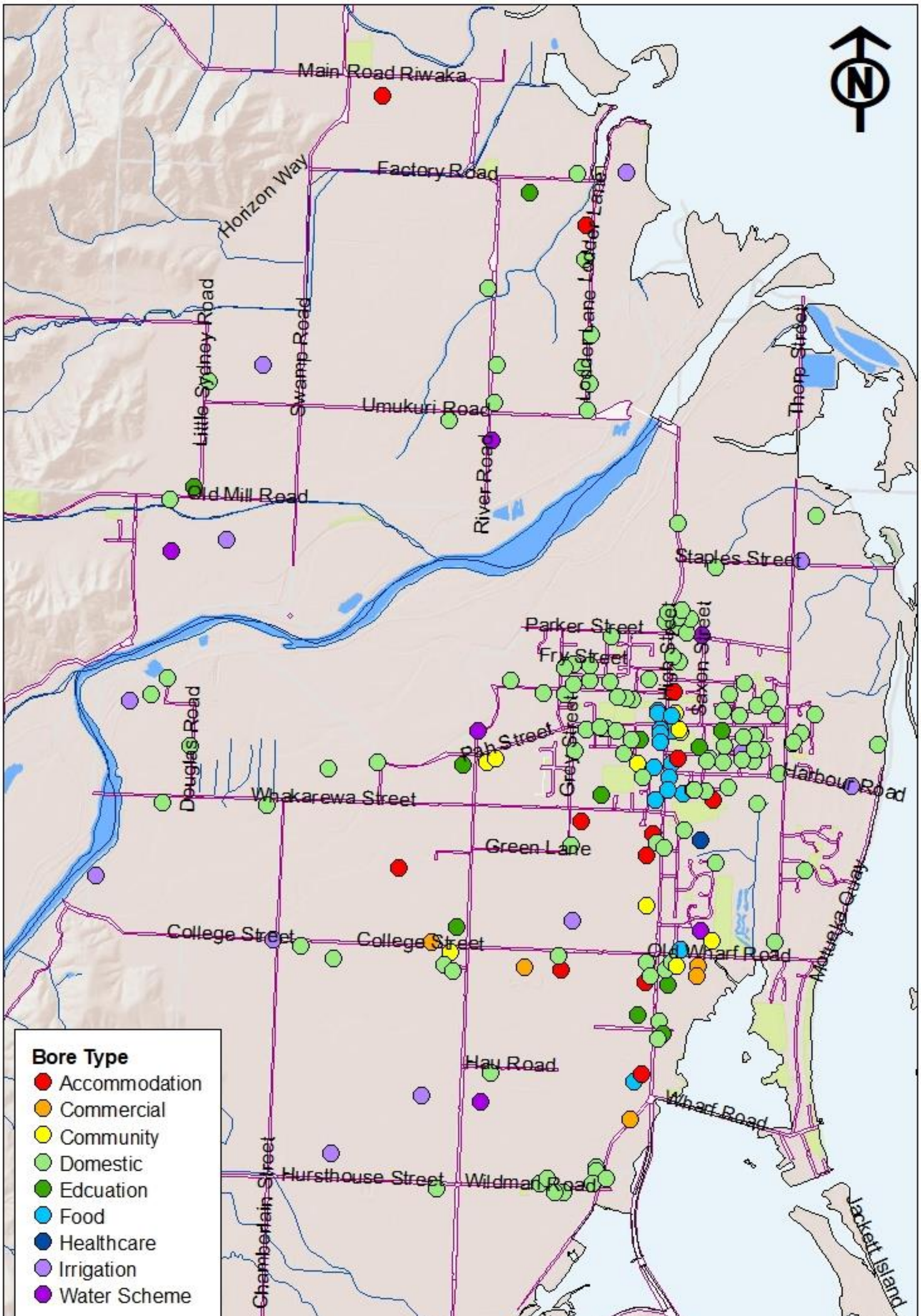


Figure 4: Category of site of the bores sampled as part of the 2019 groundwater quality survey.

3 Groundwater Quality

3.1 Groundwater Chemistry

As outlined in Section 2, various chemical parameters were tested for including minor (15 parameters), major (30 parameters), stormwater/hydrocarbons (172 parameters) and horticultural/agricultural (236 parameters). The results were compared against the Drinking Water Standards for New Zealand 2005 (Revised 2018) (DWSNZ), displayed in Tables 1 and 2. The DWSNZ has levels for substances of health significance and also aesthetic substances (can affect taste and odour but not safety). Health significant substances have a maximum acceptable value (MAV) and aesthetic substances have a guideline value (GV). Please refer to Appendix II to see the distribution of selected chemical parameters across the Motueka / Riwaka Plains.

Table 1: Aesthetic parameters for 2019 Motueka / Riwaka Plains groundwater survey.

Parameter	DWSNZ (GV)	Findings
Ammonia	1.5 g/m^3 (Odour threshold)	Nothing above the limit of detection.
Conductivity	µS/cm	Higher closer to the coast.
Hardness	200 g/m^3	Overall hardness was low (high hardness can make the water slightly corrosive).
Iron	0.2 g/m^3	Nothing above 50% of GV. Most under 10% or detection limit.
Manganese	0.04 g/m^3 (Staining of laundry) 0.10 g/m^3 (Taste threshold)	One sample above GV, also had elevated iron. Several elevated levels all in Riwaka/Brooklyn area which is known to have this issue. This is related to the geology in this area.
pH	7.0 – 8.5 pH units	Most results between 6.5 and 7.5. Slightly higher pH closer to the Motueka River and the sea.
Sulphate	250 g/m^3 (Taste threshold)	Nothing above 50% of GV. Most under 10% or detection limit.
Temperature	^oC	Generally between 13 - 17 degrees.
Turbidity	2.5 NTU	Most results under 1 NTU which indicates good quality groundwater.
Zinc	1.5 g/m^3 (Taste threshold)	Nothing above 50% of GV. Most under 10% or detection limit.

Table 2: Health significant parameters for 2019 Motueka / Riwaka Plains groundwater survey.

Parameter	DWSNZ (MAV)	Findings
Antimony	0.02 g/m^3	Nothing above the limit of detection.
Arsenic	0.01 g/m^3	Nothing above the limit of detection.
Barium	0.7 g/m^3	Nothing above 10% of the MAV.
Boron	1.4 g/m^3	Nothing above 10% of the MAV.
Cadmium	0.004 g/m^3	Nothing above the limit of detection.
Copper	2 g/m^3	Nothing above 50% of MAV. Only one sample was at 10% of the MAV, the rest under 10% or detection limit.
Lead	0.01 g/m^3	Nothing above 50% of MAV. Two samples above 10% of the MAV, the rest under 10% or detection limit.
Mercury	0.002 g/m^3	Nothing above the limit of detection.
Nickel	0.02 g/m^3	One sample above MAV, one above 50% of MAV, five above 10% MAV, the rest under 10% or detection limit. The ultramafic influence of the soils underlying Motueka/Riwaka Plains may have caused this.
Nitrate-N	11.3 g/m^3-N	Most under 50% of the MAV, nothing above.
Nitrite-N	0.06 g/m^3-N (Long term) 0.91 g/m^3-N (Short term)	Nothing above 10% of the MAV.
Selenium	0.01 g/m^3	Nothing above the limit of detection.
Herbicides	Various	Nothing above the limit of detection.
Pesticides	Various	Nothing above the limit of detection.
Semi-volatile Organic Compounds	Various	Nothing above the limit of detection.
Volatile Organic Compounds	Various	Styrene detected in one sample below 10% of MAV. The rest had nothing above the limit of detection.

3.2 Comparison to Previous Synoptic Surveys and State of the Environment Monitoring

Eight of the bores tested in the major suite were the same bores sampled in previous synoptic surveys undertaken in 1990, 2003 and 2010/2011. The Council has four State of the Environment (SoE) monitoring bores in the Motueka / Riwaka Plains which are sampled four times per year. The location of these bores can be seen in Figure 5.

The parameters which can be compared between previous surveys and SoE monitoring bores are conductivity, iron, manganese, nitrate-N, sulphate, water temperature and pH. The general trends can be found in Table 3. Please refer to Appendix III for the raw data.

Care is required in interpreting the results. Most of the synoptic survey bores have only been sampled four times since surveying began, hence it is difficult to establish any definitive trends from four data points, especially as the synoptic surveys were undertaken at different times of the year. Groundwater quality can vary seasonally due to a range of factors including changes in rainfall patterns (intensity and volume), river recharge and land use practices throughout the year. This means the results from the synoptic surveys could also be a reflection of the timing the sample was taken in the year and not an overall groundwater quality trend. The four regional SoE bores, that are sampled every four months, do provide adequate data to analyse trends.

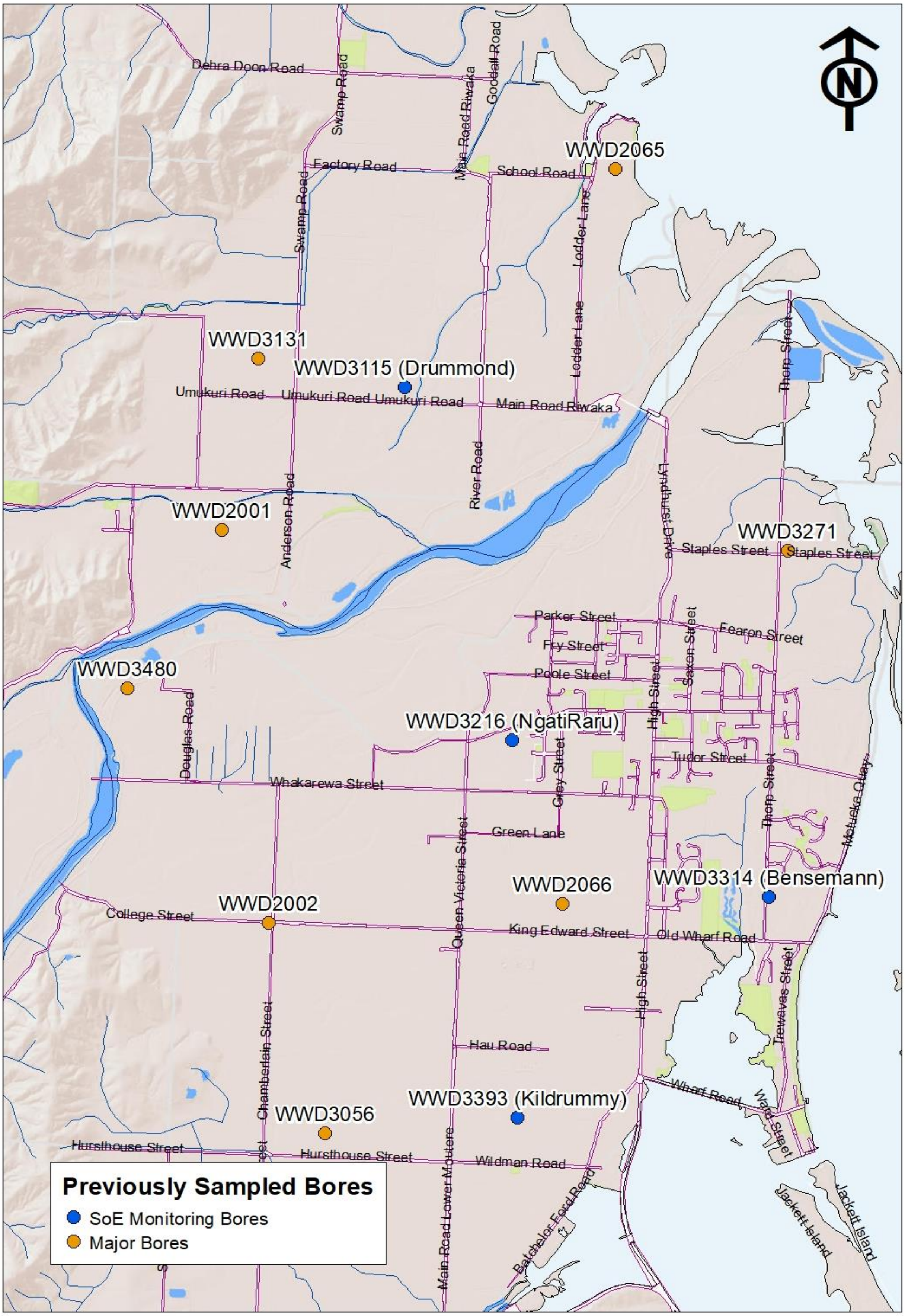


Figure 5: Location of bores sampled in previous synoptic surveys and the Council SoE bores.

Table 3: Trends from pervious synoptic surveys and SoE monitoring bores.

Parameter	DWSNZ (MAV/GV)	Findings
Conductivity	µS/cm	Trend: No major change across the plains. WWD2065 has the highest conductivity readings in every survey compared to the other bores and appears to show a slight increase throughout the years. WWD2065 is located close to the coast so an increase in conductivity is likely, however the conductivity is well within freshwater range. No other bores show a trend in conductivity.
Iron	0.2 g/m^3	Trend: No major change across the plains. No bores sampled in 2019 had iron concentrations above the limit of detection. Previous surveys have found nothing above 10% of the GV, with most below the limit of detection.
Manganese	0.04 g/m^3 (Staining of laundry) 0.10 g/m^3 (Taste threshold)	Trend: No major change across the plains. WWD2065 and WWD3131 are above 0.10 g/m^3 manganese concentrations in all previous surveys. These bores are located in an area known to have manganese from swamp deposited organic material in the soil deposits (geology) overlying the aquifer. WWD3131 appears to have a slight decrease throughout the years. WWD2065 appears to show no change. No other bores were above the limit of detection in any surveys.
Nitrate-N	11.3 g/m^3-N	Trend: No major change across the plains. All bores sampled in 2019 were under 50% of the MAV for nitrate concentration. Previous surveys also have most bores below 50% MAV.
pH	7.0 – 8.5 pH units	Trend: No major change across the plains. Most bores had pH between 6.5 and 7.5 with no major change in pH throughout the years. The pH is slightly higher in the bores located closer to the Motueka River and the sea.

Sulphate	250 g/m^3 (Taste threshold)	Trend: No major change across the plains. All bores sampled in 2019 were under 50% of GV for sulphate concentration, with most under 10%. Previous surveys also have all bores below 50% MAV.
Temperature	^{o}C	Trend: No major change across the plains. Generally the water temperature for all bores is between 13 - 17 degrees, with no apparent change in temperature throughout the years.

Overall, there has been little change in groundwater quality throughout the years, with most sample parameters below the MAV and GV for the DWSNZ. Comparing the 2019 groundwater quality results for each site against the mean (average) of the historic results for that site and the mean results from all the sites in the 2019 synoptic survey all indicates little change in groundwater quality throughout the years. Contextually, comparing the synoptic survey results against trends shown in long term SoE monitoring also shows little change in groundwater quality throughout the years. Groundwater quality for the majority of parameters has historically been below the DWSNZ MAV and GV. The 2019 synoptic survey indicate that the sample parameters continue to remain below the DWSNZ MAV and GV at the time of sampling.

3.3 National Groundwater Pesticide, Glyphosate and Emerging Organic Contaminants Investigation

Since 1998, the Institute of Environmental Science and Research (ESR) has conducted a groundwater investigation sampling every four years for pesticides in bores across New Zealand. Six bores in the Motueka / Riwaka Plains have been sampled since the investigation began, the results of which can be seen in Figure 6. The colour of the bores represents the increasing incidence of pesticide residues detected in the water samples throughout the years. Greater weighting is given to detection of pesticides in the more recent surveys.

Pesticide residue detections throughout the years do not exceeded the MAV from the DWSNZ. The two bores sampled in Riwaka (WWD4140 and WWD3115) both had terbuthylazine detected in 2018. WWD4140 has had no record of detection in any pesticides in recent years until the detection in 2018. WWD3115 has had terbuthylazine detected in the last two investigations with no obvious change residue concentration between 2014 and 2018. Of the four bores sampled in Motueka in 2018, two bores had pesticides detected. WWD23604 has previously no record of any pesticides until 2018 when terbuthylazine was detected. WWD4096 detected positively for simazine and terbuthylazine with both of these pesticides detected at this bore in pervious investigations. All three bores sampled in 2019 as part of the Motueka / Riwaka Plains groundwater quality survey had no detections of pesticide residues present in the water samples. All pesticides residues detected by ESR in 2018 were well below the maximum acceptable values in the DWSNZ.

Diazinon, simazine and terbuthylazine are agrichemicals which were commonly used in the Motueka / Riwaka Plains. Diazinon is an insecticide used to control insects on fruit, vegetable, nut and field crops. Simazine is a selective triazine herbicide for grass and weed control used commonly in berry fruit, vegetable, orchard and vineyard crops. Terbuthylazine is a selective residual herbicide for grass and weed control used commonly in certain orchard and vineyard crops.

In 2018, ESR also tested a selection of the bores for emerging organic contaminants (EOCs); those selected for EOC sampling in Motueka / Riwaka are shown in Figure 7. As this is the first time testing for EOCs, no comparisons to previous results can be made. There were two bores in Motueka which had positive detections for EOCs: WWD4096 had 3 EOCs detected, WWD23604 had 13 EOCs detected. Both WWD4096 and WWD23604 also had pesticides detected in 2018. Most of the EOCs detected originate from human body metabolisms (eg caffeine, sucralose) or are applied to the skin as sunscreens or cosmetics. Parabens were also detected which are commonly used in food preservatives. For WWD23604, the EOCs detected are commonly found in wastewater. The results from this investigation have been passed on to the Councils' utilities department for follow up to a potential sewerage leak near the bore.

EOCs do not have MAVs from the DWSNZ. As the compounds detected in WWD4096 and WWD23604 are in nanogram concentration (0.000 000 001 g), the EOCs are likely to be of low toxicity to humans. However the impacts of EOCs in the environment and ecological systems are largely unknown.

ESR also tested glyphosate in a selection of bores for the first time in 2018. Glyphosate was not detected in any of the bores tested in the Tasman region (WWD4096 and WWD23604 were tested from the Motueka / Riwaka Plains).

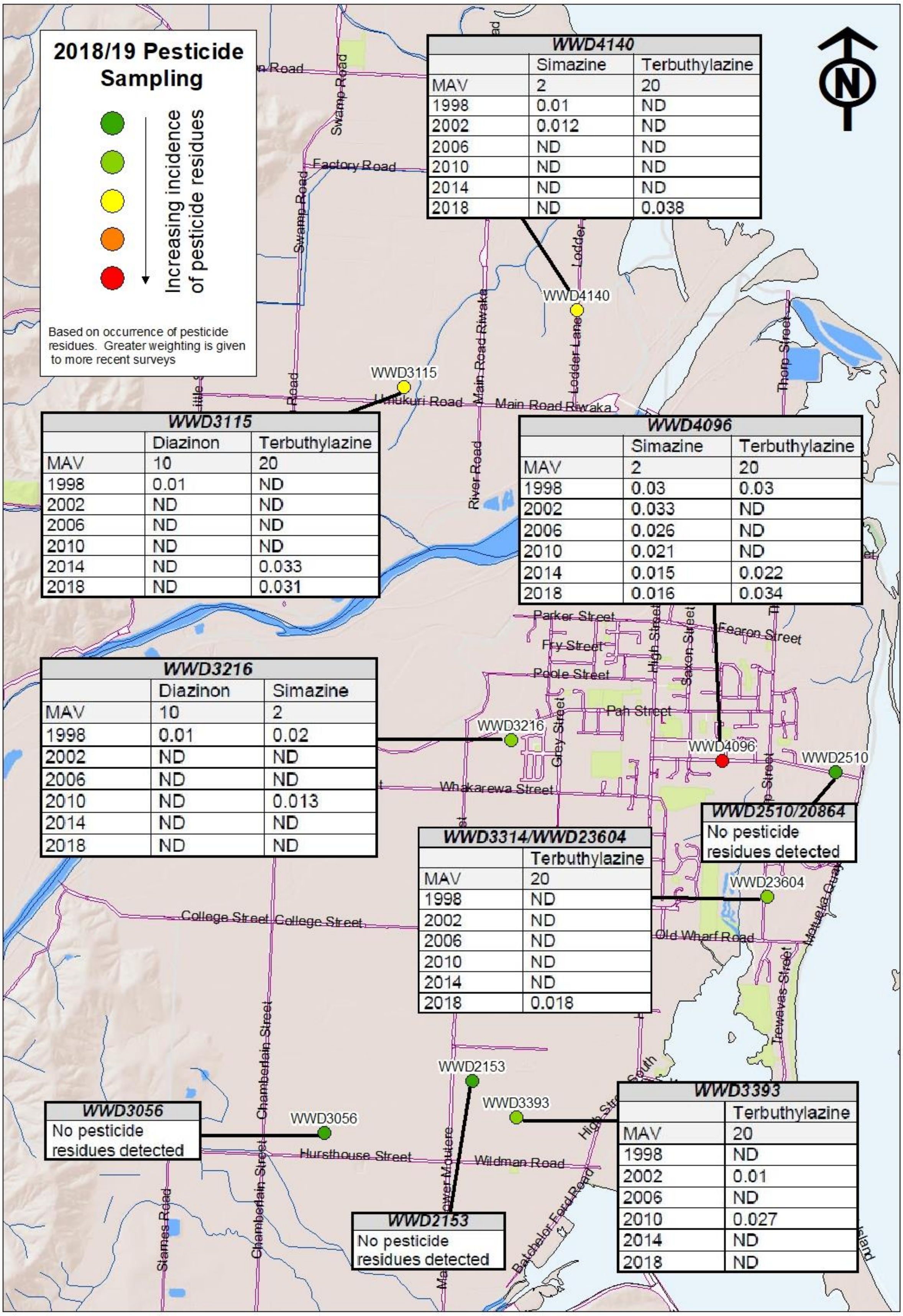
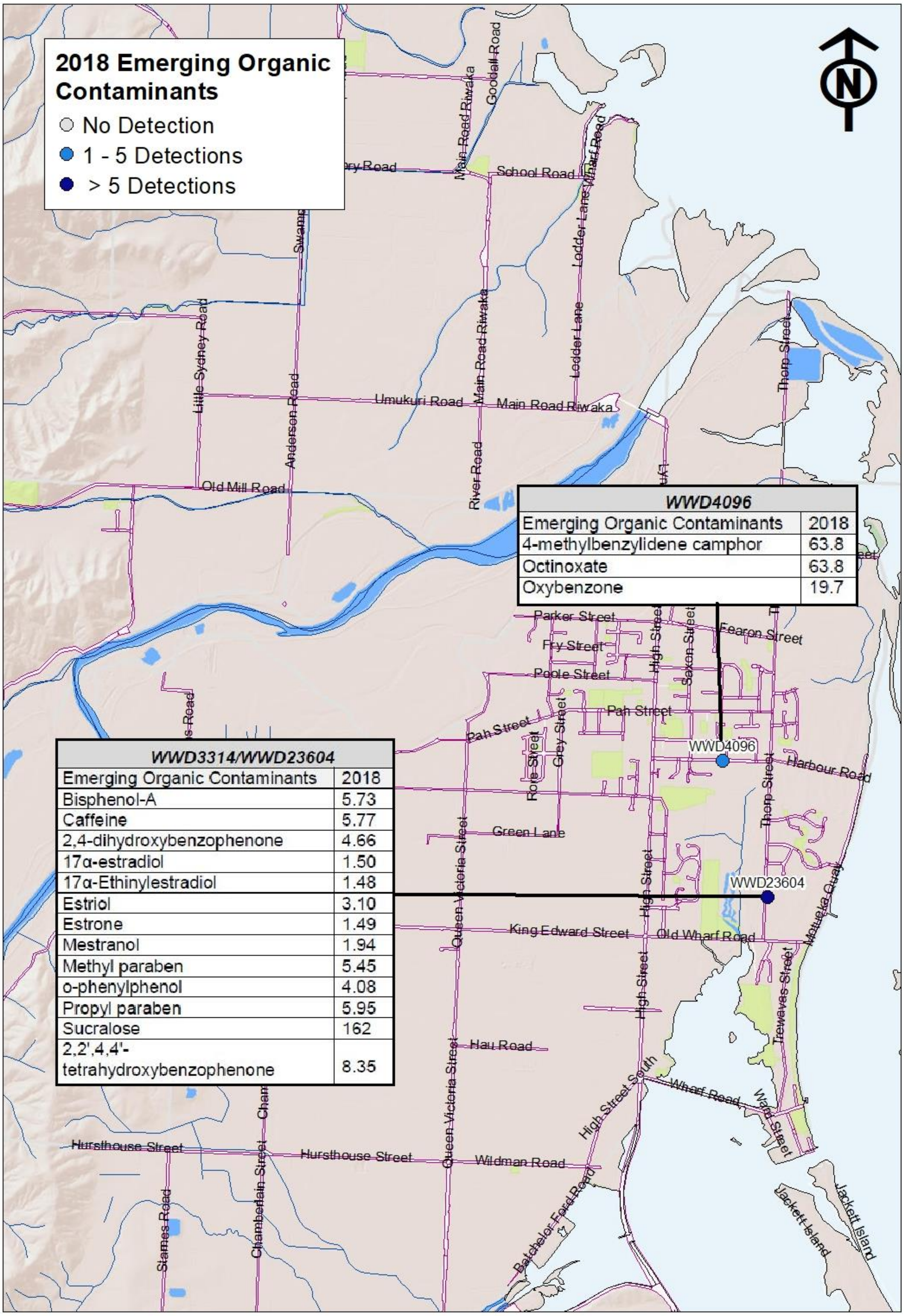


Figure 6: Combined pesticide results: ESR national groundwater pesticide survey (1998 to 2018) and 2019 Motueka / Riwaka Plains survey.
ND means No Detection. Measured in µg/L – this is equivalent to 0.000 001 g per litre (10 parts per million).



WWD4096	
Emerging Organic Contaminants	2018
4-methylbenzylidene camphor	63.8
Octinoxate	63.8
Oxybenzone	19.7

WWD3314/WWD23604	
Emerging Organic Contaminants	2018
Bisphenol-A	5.73
Caffeine	5.77
2,4-dihydroxybenzophenone	4.66
17α-estradiol	1.50
17α-Ethinylestradiol	1.48
Estriol	3.10
Estrone	1.49
Mestranol	1.94
Methyl paraben	5.45
o-phenylphenol	4.08
Propyl paraben	5.95
Sucralose	162
2,2',4,4'-tetrahydroxybenzophenone	8.35

Figure 7: ESR 2018 national groundwater emerging organic contaminant investigation results for the Motueka / Riwaka bores.
Measured in ng/L – this is equivalent to 0.000 000 001 g per litre (1 part per billion).

3.4 Bacteriological Contaminants

There are two general indicators of the bacterial quality of groundwater: total coliforms and *Escherichia coli* (*E.coli*). Total coliforms are a reflection of organic material in the water and are not necessarily illness causing. *E.coli* is a bacterium from the gut of warm blooded mammals and is an indication that faecal contamination of the groundwater may have occurred.

It is standard practice to sterilise the sampling tap before taking any bacterial water samples. This reduces the risk of the tap contaminating the water sample. In most instances the tap was sterilised using a gas burner, however some taps/fittings were plastic and not able to be flamed, these were only sterilised with alcohol. Alcohol sterilisation alone is not ideal therefore there is a very low but potential risk that unsterilized plastic taps/hose pipes may be the cause of some of the total coliform results.

With regard to *E.coli*, four samples were positive with levels of 1 MPN/100mL of *E.coli* in three samples and 2 in the fourth (Figure 8). In all four instances, total coliforms were also detected which is expected.

All positive *E.coli* results were followed up with another sample. There was one resample which came back with a positive *E.coli* result. We are working with the property owner to identify where potential sources of *E.coli* could be entering and contaminating their bore. Three other instances resulted in the follow up sample being clear (no *E.coli* detected). Of the resamples which came back clear, one was put down to the proximity of the bore to the onsite wastewater pump. Another may be due to the proximity of the bore to recent land disturbance.

Total coliforms were detected on 34 occasions (Figure 9). There is no level outlined in the DWSNZ for total coliforms, however their detection could be an indication that the groundwater is being exposed to surface water or localised interference (such as poor borehead security or very shallow bore).

Overall the bacterial water quality was considered to be very good with only 2% of samples positive for *E.coli* in the initial sample and 18% contained total coliforms. It is important the Council continue to monitor for *E.coli* and total coliforms in the Motueka / Riwaka groundwater as it can be an early indication that something is or has changed.

Another faecal organism that is very resistant to treatment and can survive for long periods in water include certain protozoa organisms (such as giardia). Protozoa were not sampled for in this project as they are expensive and time consuming. However the risk of protozoa contamination for most of Motueka / Riwaka is likely to be low given the lack of animal farming and the natural filtration that the groundwater experiences. The Massey study commissioned by the Ministry of Health did not detect any protozoa in shallow bores at various sites in New Zealand (Jessamine et al., 2018). Having said that, there is still a potential risk of protozoa contamination.

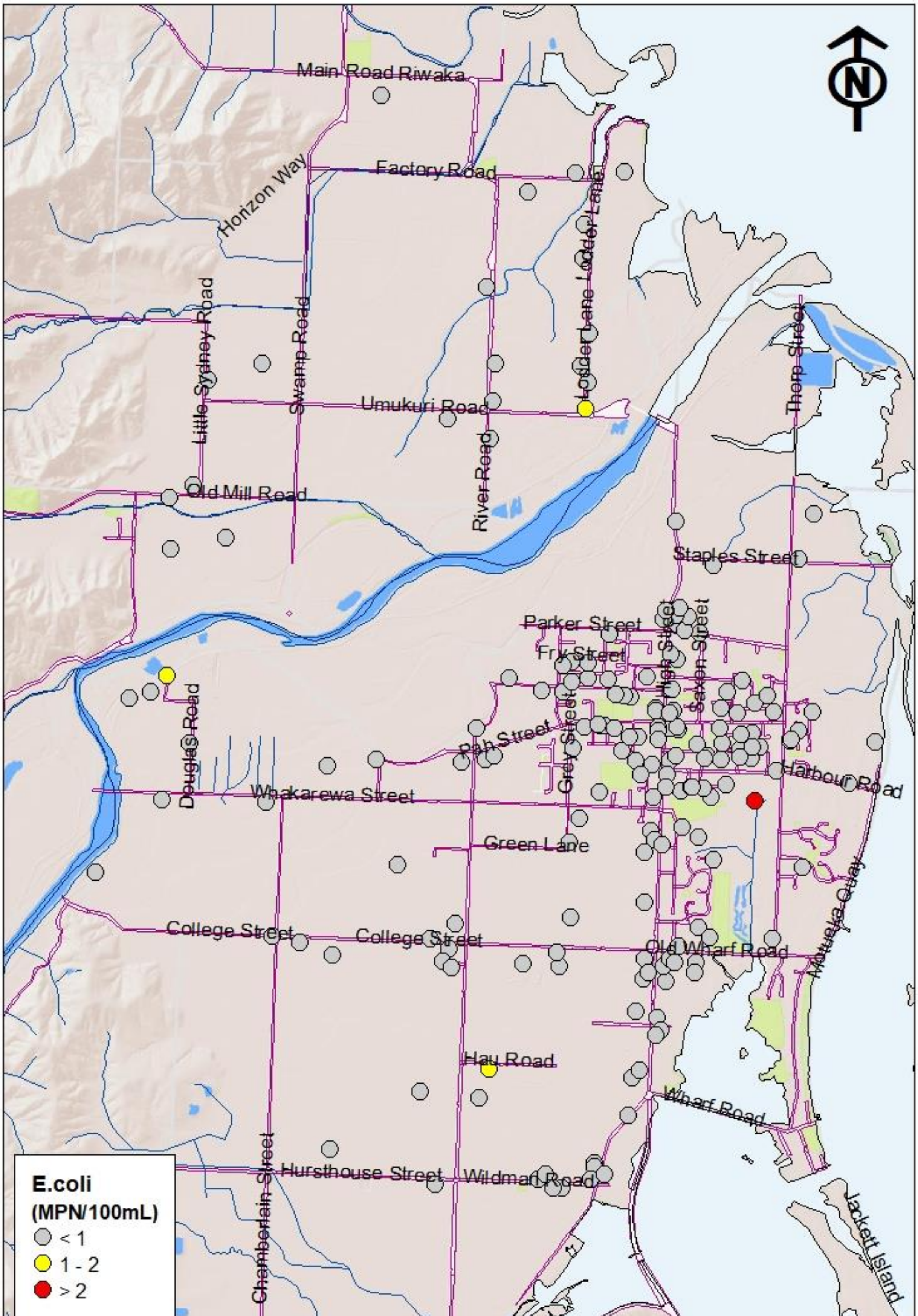


Figure 8: *Escherichia coli* results from the bores sampled as part of the 2019 groundwater quality survey.

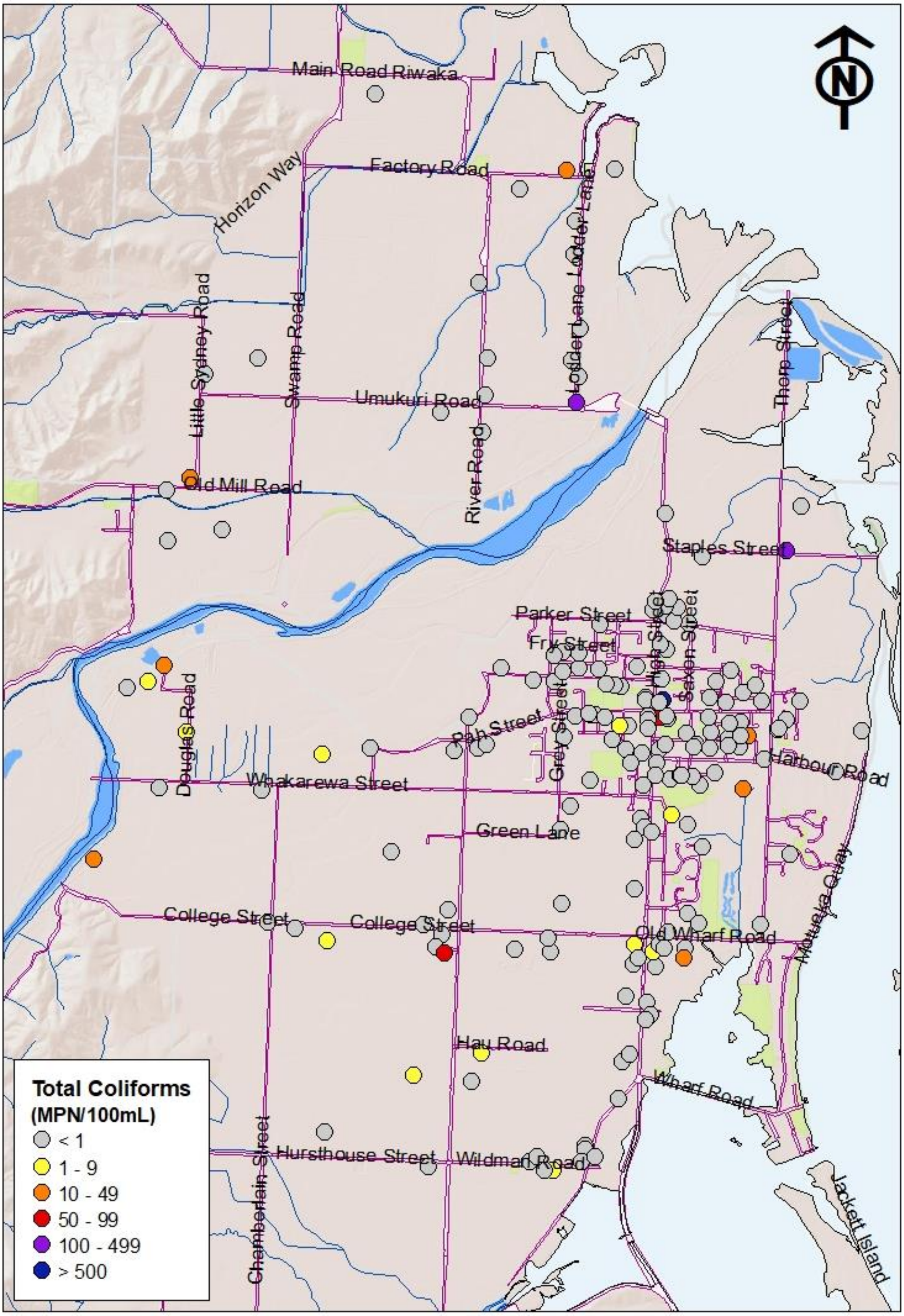


Figure 9: Total coliforms results from the bores sampled as part of the 2019 groundwater quality survey.

4 Rivers and Springs Quality

The ten surface water (river and spring) sites water quality were analysed against numerical attribute states for the protection of river ecosystem health, aesthetics and human health (please refer to data in Appendix IV).

The four rivers/streams in the Motueka / Riwaka Plains (Motueka, Riuwaka, Little Sydney and Brooklyn) all recharge the underlying aquifer system. The Motueka River recharges most of Motueka, with the Riuwaka, Little Sydney and Brooklyn providing localised recharge in areas near those rivers. The five springs are located near the coast where the groundwater emerges to the surface and flows to the sea. On average the recharge water and springs were of good quality when compared against attribute state values in Appendix IV, both for human and ecological health.

Spring water can be slightly lower in quality than water taken directly from the aquifer. The gradient of the land near the coast where the springs emerge is shallow causing the water to flow slowly which allows the water to pool in some places and become stagnant. This can be seen by comparing *E.coli* counts between the rivers and springs. *E.coli* is low in all four rivers with the average of the rivers 70 MPN/100mL, which is well below the 260 MPN/100mL trigger value set in the National Policy Statement for Freshwater Management (NPSFM) for contact recreation. In the springs, *E.coli* is slightly higher, with the average of 165 MPN/100mL but still below the NPSFM contact recreation trigger value. A possible reason for a higher *E.coli* count in the springs could be due to the ponded water attracting wildlife and birds which defecate directly into the water. Rivers generally have higher flows with aeration (riffles) allowing for greater dilution, better exposure to ultra-violet light (UV), with less opportunity for stagnation and ponding.

Naturally pH in the river water is around 6.5 – 8.5. This recharge water passes through the aquifer and interacts with the soil and rocks, resulting in the pH naturally dropping to around 6 – 6.5 as it emerges in the springs.

Woodland Stream (flows next to the Motueka Recreation Centre) was also sampled as this waterway runs through the eastern Motueka township. Water quality in this stream is highly affected by overland surface flow inputs from surrounding lifestyle blocks and urban stormwater between High Street and Thorp Street. This water had the highest *E.coli* out of all river and spring sites taken with elevated concentrations of dissolved reactive phosphorus and nitrates (for surface water) which could lead to excessive algae growth (eutrophication) in the stream, particularly during warmer days of summer. In November 2019, the nitrate concentration was 1.7 g/m^3, which is well above the Government's new surface water nitrate concentration proposal limit (Ministry of the Environment, 2019). High coverage of filamentous green algae was observed in December 2019 during a Council habitat assessment which most likely was caused from the elevated nutrients in the stream.

5 Public Health Risks

5.1 Bore Construction Requirements and Permitted Take Provisions in the Tasman District

The construction, take and use of bore water in the Tasman District area is governed by the Tasman Resource Management Plan (TRMP) in Chapter 16, Clause 16.12 (reproduced below).

16.12 BORE CONSTRUCTION OR ALTERATION

16.12.2.1 Permitted Activities (Bore Construction or Alteration)

The construction or alteration of a bore is a permitted activity and may be undertaken without the need for a resource consent, if it complies with the following conditions:

(a) The bore extends to a depth of no more than 8 metres below the natural ground level.

(b) The bore is not within 20 metres of the bank of any watercourse.

(c) The bore is not within 20 metres of any stopbank measured from the landward limit of the toe of the stopbank.

(d) The bore is not within any floodway of any river.

(e) The bore is not drilled.

(f) The bore is not within 20 metres of any domestic wastewater treatment and disposal system.

(g) The bore is not in the coastal margin of the Hau Plains or Delta zones or in the coastal margin of the Marahau Zone.

(h) The bore is sited, lined and capped to prevent surface water or other contaminants entering the bore.

Note: The construction of a bore as a permitted activity does not confer any right to take water.

If the bore is driven and less than 8 m deep then no consent is required, provided the bore meets the other requirements. The main area of interest is the requirement that the bore is protected to ensure no contaminants or surface water can enter the bore. Many of the sampled bores did not meet this requirement.

Chapter 31, Clause 31.1.2.1 provides for up to 10 m^3 per day of water to be taken in the Motueka / Riwaka Plains without a consent.

5.2 Bore Water Security

Unlike surface water, many of the processes that affect the quality of groundwater occur underground, out of sight, so cannot be observed directly. Our understanding of how a groundwater system works is largely obtained by deduction from indirect observation of recharge sources i.e. river/stream, rainfall and overlying land drainage. The quality of the recharge sources and land use effects can affect the security of groundwater quality.

Secure groundwater is defined in the DWSNZ as groundwater "demonstrated that contamination by pathogenic organisms is unlikely, because the bore water is not directly affected by surface or climate influences" (Ministry of Health, 2018). Generally, the water abstracted from the Motueka / Riwaka Plains shallow aquifers may not meet this definition because of the nature of the aquifer and the risks associated with it.

5.3 Requirements for Drinking Water

There are multiple legislative requirements for the provision of drinking water that relate to that water being potable. The DWSNZ outlines what is needed to be demonstrated to show that the water complies and is potable (Ministry of Health, 2018).The DWSNZ covers the requirements for community networked drinking water supplies (bore supplies more than 25 people or supplies drinking water from the place where the supply is to one or more other properties, by means of a pipe connecting those properties).

Self-supplies are also defined in the DWSNZ/Health Act but are generally outside the scope of the requirements. These types of individual supplies are covered under the Building Act and there is a requirement that the water supplied for drinking must be potable (Ministry of Business, Innovation and Employment, 2019). Note this is not regularly checked once building sign off has been made by the Council.

Food premises are covered under the Food Legislation regulated by Ministry for Primary Industries and are generally required to have a Food Control Plan (FCP). This must cover a brief risk assessment of the water supply. Most of the food premises sampled would not meet the requirement for secure groundwater, and had no treatment in place. An annual water test is also required. A training session on bore security for the top of the south Environmental Health Officers (EHOs) will be scheduled in the future to address this.

5.4 Borehead Security

Proper bore construction including bore head protection is an essential requirement for establishing bore water security under the DWSNZ and also important for the protection of groundwater quality in the aquifer that the bore intercepts. As a minimum requirement, bore construction should comply with the Environmental Standard for drilling of soil and rock (NZS 4411: 2001).

A bore that has been producing water of good quality can sometimes become polluted. Pollutants can enter the aquifer with the water as it percolates from the surface, or directly via the bore shaft itself. One potentially major pathway for contamination that is often overlooked is the conduit provided by a poorly sealed bore, particularly during a flood or after heavy rain. Contaminants can enter directly down the bore shaft or down the junction between the casing and the soil. To protect the groundwater against this source of contamination it is essential to design and construct the bore head to protect against such contamination from the surface, see Figure 10. Bores should be secured in this manner regardless of the use made of the groundwater abstracted from them. Groundwater contamination can persist for a long time and affect a large area.

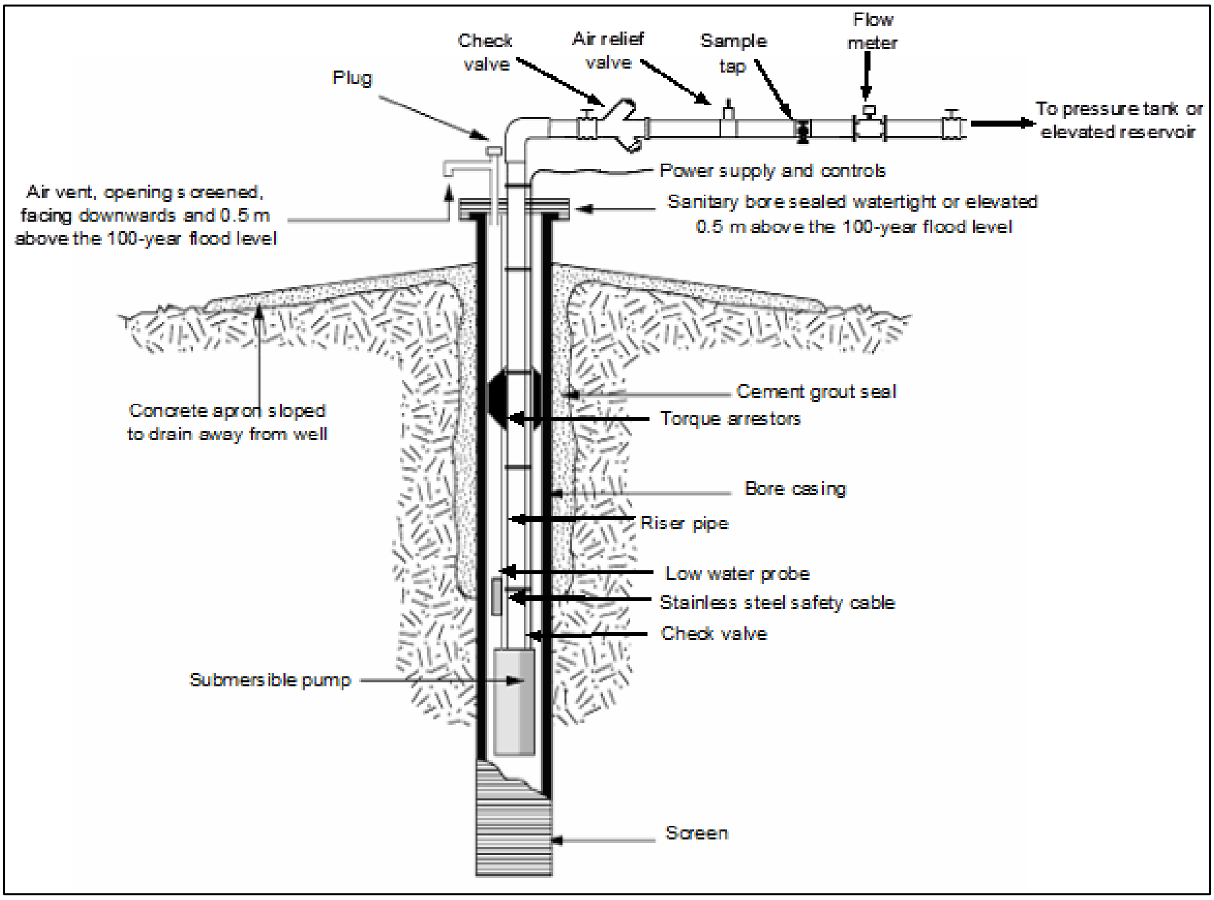


Figure 10: Key components of a bore.
Reproduced from Ministry of Health (2010).

Sources of contamination include seepage from underground fuel storage tanks, effluent discharges, septic tanks, waste ponds, offal pits, industrial areas, leaking sewers and landfills. If possible, new bores should be located away from known sources of potential contamination. Disused bores are a special pollution hazard because contaminants can find their way directly into the aquifer. Because there is not a net flow of water out of the bore, any water entering the bore from above will tend to end up in the aquifer. Disused bores should be made safe according to the requirements of the local regional Council. A nearby non-secure bore head is not necessarily part of the water supply itself, however, it is a potential threat to the supply that needs to be managed through the supply's water safety plan, just as any other potential contamination source in the capture zone would be. Regional and Unitary Authorities should be aware of old or disused bores. Old bores that have been shut down need to be located and inspected and the borehead repaired if necessary.

The design and construction of a bore water supply should effectively prevent the ingress of contaminants from the ground surface by using a grout seal. Mixing of hydraulic or aquifer units of different water quality should also be prevented. The borehead should thereby minimise the possibility of contamination of the aquifer from the surface due to back-siphoning, by contaminants passing down the outside of the bore casing due to a poor seal between the casing and the ground, or through cracks in the borehead or casing.

The possibility of backflow of contaminated water from the treatment plant or distribution system down into the bore should also be guarded against by the use of a backflow prevention device. Backflow is defined as a flow that is contrary to the normal intended direction of flow. Increasingly, sludge and/or fertilisers are being applied to pasture by pumping them into the flow of water (which is often groundwater) being used for irrigation; this is a classic situation where contamination by backflow can occur.

The water supplier should ensure that all groundwater takes from an aquifer have adequate backflow protection. The backflow protection programme should require that bores are drilled, constructed and maintained in a manner that avoids any contamination of, or cross-connection with, groundwater aquifers. This should include ensuring that borehead construction on all bores incorporates a boundary device and, where required, a flow measuring device. This is standard practice in Tasman where additives are used in conjunction with irrigation.

5.5 Findings in Relation to Motueka / Riwaka

As part of the sampling component each well/borehead was inspected where possible. The borehead can be loosely described as the area where the driven pipe leaves the ground. Details of the well/borehead were recorded along with photos. As a result 95 out of 184 wells/boreheads were sighted and are likely to be representative of all wells and bores in the area. Those unable to be sighted were generally a result of being under a structure or the location of the borehead itself was not known. Only the well/borehead and immediate area surrounding it was checked as part of this project; a wider catchment risk assessment was not undertaken.

The dwellings and smaller private supply bores (churches, schools, food premises) were generally a PVC/plastic pipe driven directly into the ground. The top layer of groundwater is reported to be 6 - 8 meters below ground levels in most of the sampled area. All of these smaller bores had surface mounted pumps which were located next to the borehead itself and in an enclosure of some sort. Where possible the site owner/occupier was met and details about the bore asked. In many cases the depth and actual site of the borehead was unknown. In all cases the borehead or pump itself had a non-return valve which reduces the risk of water flowing back into the bore and aquifer.

There were numerous occasions where bores supplied more than one property. Some of these supplies may be defined as networked supplies under the Health Act, however further investigation into these was outside the scope of the report.

Council have three bore water supplies within the area including Motueka reticulated water supply (located near the Motueka Recreation Centre) and the Kaiteriteri/Riwaka reticulated water supply (located in Riwaka). These boreheads are in excellent condition and are raised above the ground. While it was not part of this project it is likely that the boreheads would meet the requirements in the DWSNZ (see Figure 11).

Figure 11: Examples of Council reticulated water supply bores from the 2019 Motueka / Riwaka Plains survey.

The community water supply (Council and private supplies), irrigation and large industry bores were generally steel pipe bore casings with a separate extraction pipe. Some of those private bores sighted had been modified or not appropriately sealed affecting the borehead security and potentially allowing access to birds and vermin along with dust and dirt. Most of these where not sealed at ground level. Examples of boreheads that have been modified or poorly sealed can be seen in Figures 12 and 13.

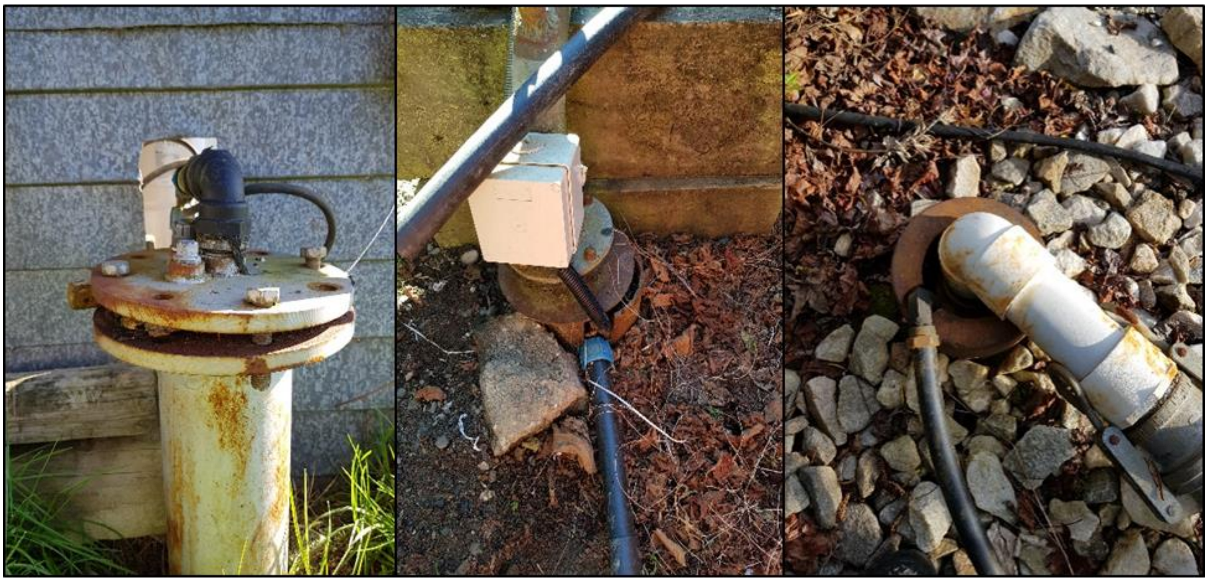


Figure 12: Examples of modified or poorly sealed boreheads from the 2019 Motueka / Riwaka Plains survey.

Figure 13: Examples of poor private boreheads / practices from the 2019 Motueka / Riwaka Plains survey.

There were also a number of concrete lined wells seen throughout the area, some of which were in use. These were in areas where the groundwater level is higher (closer to ground level). These wells are more prone to contamination as they often can have gaps between the well liners and removable lids (see Figure 14).

Figure 14: Examples of wells from the 2019 Motueka / Riwaka Plains survey**.**

Some schools, accommodation and food premises had treatment providing disinfection by UV. This is a very common type of treatment for all types of water supplies. The Council Kaiteriteri/Riwaka reticulated water supply is UV disinfected, with chlorine added during the peak months to reduce the risks due to excess water consumption and the aging network. The Council Motueka reticulated water supply is currently untreated, however Council is evaluating tenders for the construction of a water treatment plant for the new Parker Street well field located in Motueka which will include UV treatment and provision for chlorination. Consultation is underway for the four Council reticulated supplies that are currently not chlorinated (which includes the Motueka and Kaiteriteri/Riwaka water supplies, see comments in Section 6.1 relating to new water regulations). The Talleys Motueka private factory supply is currently chlorinated.

The main risks found during the site assessments of wells/boreheads included:

- Well/boreheads next to rubbish storage, stormwater drains and in low-lying areas
- Chemical storage in the vicinity of well/boreheads
- Historic driven pipes not sealed at ground level or appropriately sealed
- Wells with unsealed well liners and inadequately fitting lids
- Lack of records on individual bore supplies due to them being a permitted activity

Some of these activities are a risk to the groundwater by creating pathways for contaminants to get into the aquifer. The presence of UV disinfection units in some schools, accommodation and food premises also shows an acknowledgement of the risk.

While some of the practices encountered could affect the groundwater, there were also some very good examples of private bores being well sited and protected (see Figure 15).

Figure 15: Examples of good private boreheads / practices from the 2019 Motueka / Riwaka Plains survey.

The Council needs to remain aware of potential contamination pathways into the Motueka / Riwaka Plains aquifer. While the results show stable water quality with only sporadic and low level faecal contamination (likely sampling or localised contamination), the risk remains nonetheless due to the nature of the aquifer.

6 Discussion

6.1 Potential Impacts of New Drinking Water Regulations

Following the Havelock North outbreak in August 2016, the subsequent Government Inquiry recommended an array of substantial changes including a review of the DWSNZ, removal of secure bore status for groundwater supplies, establishment of an independent water regulator, amending the Resource Management Act 1991 and mandating universal treatment for all supplies (networked and specified self-supplies) (Department of Internal Affairs, 2017).

The Government introduced the Taumata Arowai – Water Services Regulator Bill in December 2019 for the establishment of an independent regulator, responsible for the proposed new drinking water regulatory system, and for a small number of new functions relating to the regulation and performance of wastewater and stormwater networks. The Taumata Arowai – Water Services Regulator Bill was passed by parliament and gained royal ascent on the 6th of August 2020. (New Zealand Parliament, 2020a). The Taumata Arowai government department has been created and the functions for drinking water are outlined in the Water Services Regulator Bill (New Zealand Parliament, 2020b).

The Water Services Regulator Bill outlines significant reforms, which could have wide implications for the vast number of water supplies located throughout the Tasman District Council boundaries. For instance, if established the regulator will ensure greater protection and identification of risks within the source waters, therefore, water suppliers having to address the vast number of unsecure bores (borepipes not sealed, modified etc). The addition of a residual disinfectant is also proposed to be mandated and in most cases this is chlorine. Furthermore, indications are that the regulator will require all suppliers such as marae, community halls, schools and very small networked supplies (except individual domestic self-suppliers) to be part of the regulatory system and to provide safe drinking water on a consistent basis. Ramifications of this are potentially increased costs to all water suppliers, with indications being that Territorial Local Authorities (TLA) may have to assist these smaller water suppliers to ensure adequate treatment for these communities.

The indicated future requirements of the regulator will radically change the current environment. Presently, under the Health Act 1956, Part 2A Section 69J specified self-supplies must be at least registered, with a technical definition of a community water supply providing water to more than 25 people across a legal boundary to another title not owned by the supplier (Ministry of Health, 1956).There were instances in the 2019 Motueka / Riwaka Plains groundwater quality survey where some of the supplies found provided water to more than one property and would fit into this definition. The Water Services Regulator Bill definition of a drinking water supply covers all supplies that are not single stand-alone dwellings. So technically any supply providing water to more than one dwelling could be captured under the legislation. The impact on both Council and residents could be significant. Initially each supply will need to be registered which would require assessment of each individual water supply within Motueka. Whether this would be done by the new regulator or expected of Council is unknown at this stage.

The Havelock North Enquiry recommended that appropriate and effective treatment for all suppliers, including residual reticulation disinfectant should be mandated by law (Department of Internal Affairs, 2017). This is proposed in the Water Services Regulator Bill, and a number of the water supplies sighted on this survey were supplying to other properties, and may also have to be treated with a residual disinfectant. There are proposals for exemption of this requirement but applications would have to be made to the Chief Executive of the new water authority.

The consequences of proposed legislation changes including the creation of the new regulator (Taumata Arowai) will substantially change the dynamics of drinking water in New Zealand, and will add many additional requirements on all water suppliers.

The Tasman District Council Engineering services department is actively working over the next three years to ensure that all Council reticulated water supplies will comply with the requirements of the drinking water standards and proposed legislative changes detailed in the Water Services Bill.

6.2 Summary Conclusions

Overall, groundwater in the Motueka / Riwaka Plains is of good quality with regards to water chemistry. The 2019 survey found the majority of the chemical parameters were well below the DWSNZ for both the health significant and aesthetic factors. Comparisons with previous synoptic surveys confirmed that the groundwater quality has remained consistently of good quality, with no significant changes throughout the years. River water quality, which is the main source of recharge for the Motueka / Riwaka Plains aquifer is also of good quality.

All pesticides residues detected by ESR in 2018 were well below the maximum acceptable values in the DWSNZ. The ESR survey also identified a potential sewerage leak from the EOCs detected in one bore, which is being followed up accordingly by the Council utilities department. No glyphosate was detected in any of the selected Tasman region bores.

The survey did identify various risks to the security of the unconfined/semiconfined (leaky) aquifer which could have risks to public health. These include inappropriate sitting of bores, boreheads not sealed and the storage of chemicals in close vicinity to the bores. In most instances these were not intentional but more of a lack of knowledge. The presence of UV disinfection units in some places acknowledges the potential contamination risk to the groundwater.

7 Recommendations / Next Steps

- Increase awareness of private bore owners on how to reduce their risk of bore contamination. Council will be providing relevant information on the Council website and via the Newsline magazine.

- Increase awareness for bore drillers and non-Council water service agents (private and community) on the importance of borehead security and the need to improve this. Education/training for Council Environmental Health Officers by appropriate qualified Drinking Water Assessors will be provided to address borehead security in relation to food premise inspections.

- It is important that the Council continues to be involved in the ESR pesticide, glyphosate and EOCs survey in the future. The 2018 survey uncovered a potential sewerage leak in one of the bores sampled. The Council utilities department has been provided with the results from the EOCs data and they are following up on the potential sewerage leak accordingly.

- Council includes sampling for *E.coli* and total coliforms as part of the SoE groundwater monitoring programme. These parameters can provide an early indication of bacterial contamination in the aquifer and near the bore.

- Council considers the need for full reticulation of the area because of the potential contamination risk to the shallow bores. The need to consider reticulation could also be influenced by the new water services bill.

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Matt Molloy

Matt Molloy has over 25 years of public health experience firstly with the Nelson Marlborough District Health Board and as a public health consultant over the last decade. Matt has a Diploma in Environmental Health Science and a Post-graduate Diploma in Drinking Water Assessment. Matt has specialised in drinking water compliance and consults directly to many District Health Boards in New Zealand as a Drinking Water Assessor and also to the World Health Organisation as a Water Sanitation & Hygiene Specialist. Matt also consults to many Councils in New Zealand providing drinking water safety plans, catchment management plans and water quality reports.

Melanie Westley

Melanie Westley is the Science Officer – Groundwater at the Tasman District Council. She specialises in analysing groundwater quality and quantity across the Tasman region. Trained as a Natural Resources Engineer, she also has experience in designs utilising ecological systems and groundwater resources.

Appendix I

There were several bottles for each water sample depending on the suite the water was to be analysed for as detailed in Table 4.

Table 4: Sample bottle treatments.

Bottle	**Material**	**Preservative**
Minor suite		
1 x 500 mL (UP500)	Polyethylene	None
1 x 100 mL (NWU100)	Polyethylene	None
1 x 400 mL (SterThio)	PET container, PP lid	$Na_2S_2O_3$
Major Suite		
1 x 500 mL (UP500)	Polyethylene	None
1 x 100 mL (NWU100)	Polyethylene	None
1 x 400 mL (SterThio)	PET container, PP lid	$Na_2S_2O_3$
Stormwater/Hydrocarbon Suite		
1 x 500 mL (UP500)	Polyethylene	None
1 x 100 mL (NWU100)	Polyethylene	None
1 x 400 mL (SterThio)	PET container, PP lid	$Na_2S_2O_3$
1 x 500 mL (Org500)	Amber glass, Teflon lined lid	None
2 x 40 mL (VOC40)	Amber glass, Teflon lined lid	Ascorbic Acid
Horticultural/Agricultural Suite		
1 x 500 mL (UP500)	Polyethylene	None
1 x 100 mL (NWU100)	Polyethylene	None
1 x 400 mL (SterThio)	PET container, PP lid	$Na_2S_2O_3$
1 x 500 mL (Org500)	Amber glass, Teflon lined lid	None

Appendix II

Distribution of selected chemical parameters across the Motueka / Riwaka Plains.

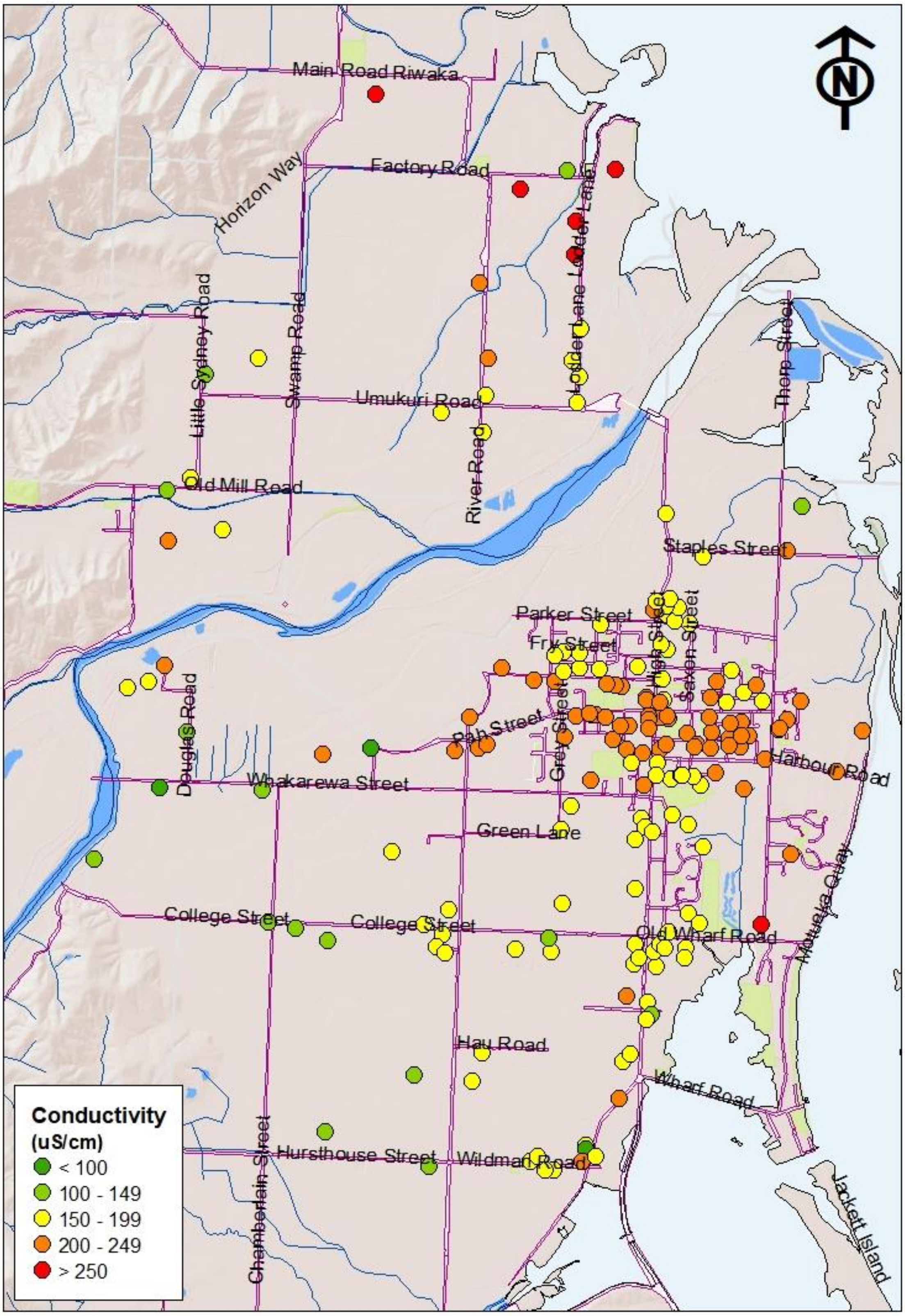


Figure 16: Distribution of conductivity across Motueka / Riwaka Plains from 2019 survey. There is no DWSNZ MAV or GV for conductivity.

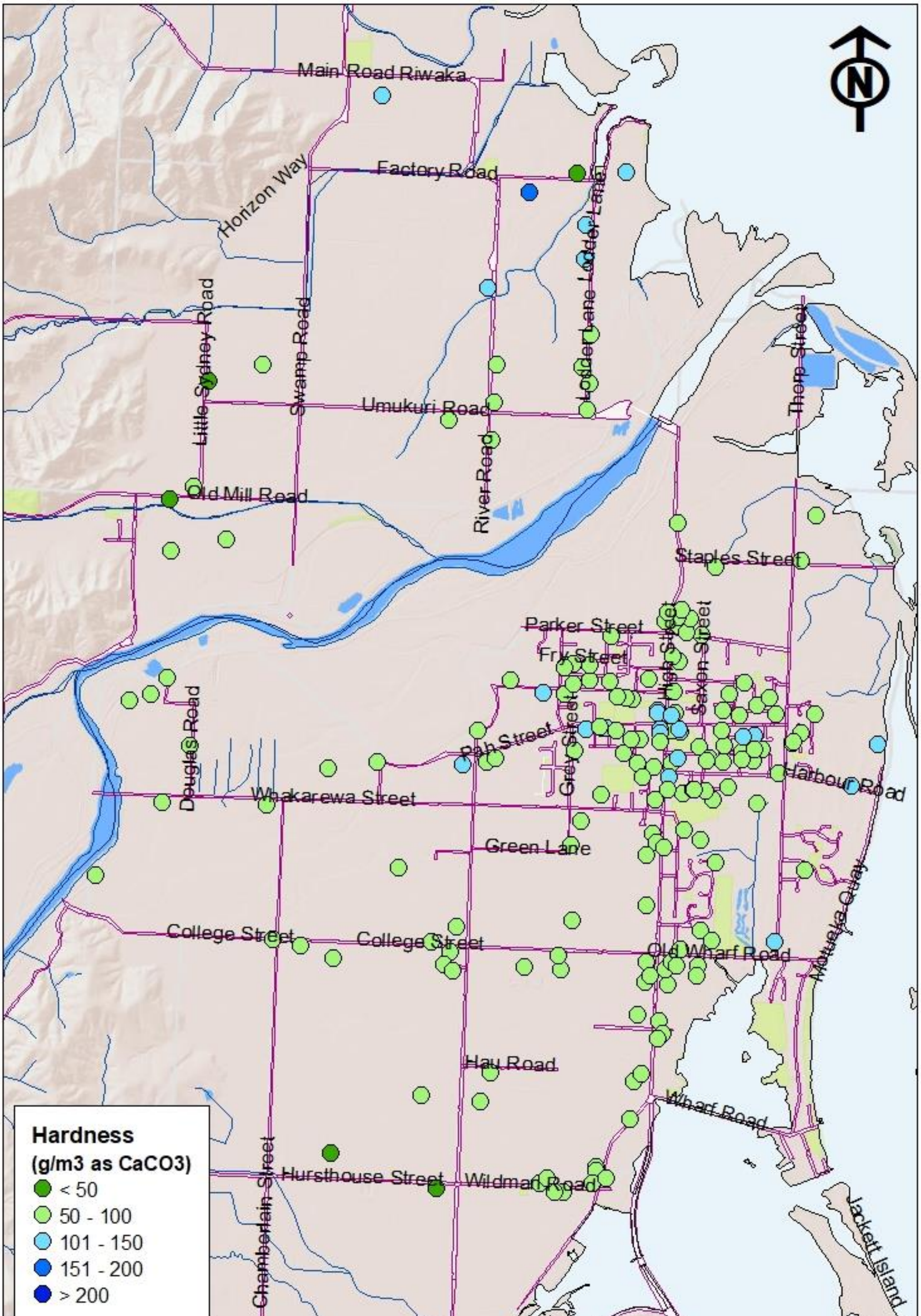


Figure 17: Distribution of hardness across the Motueka / Riwaka Plains from 2019 survey. The DWSNZ GV for hardness is 200 g/m^3 as $CaCO_3$.

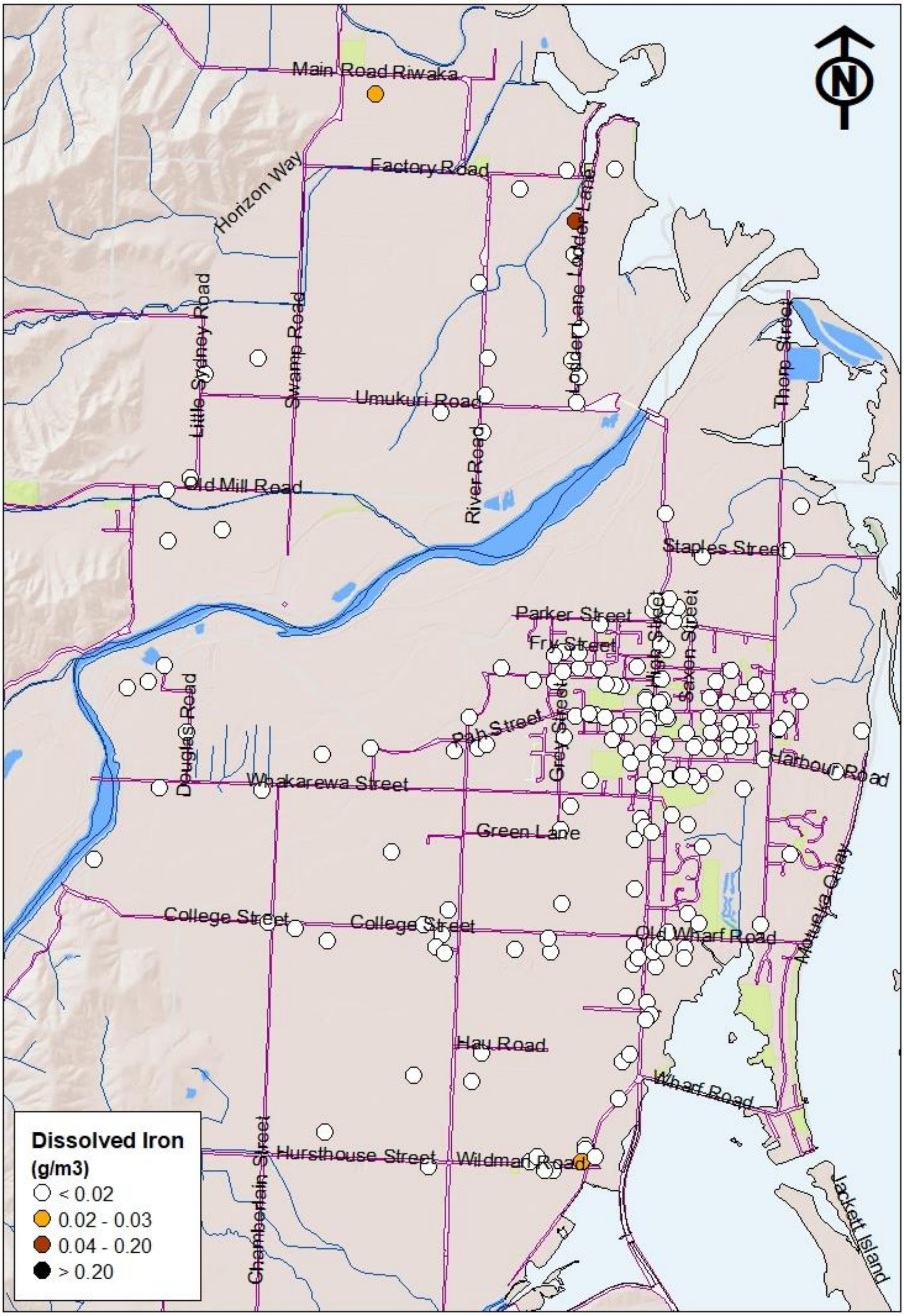


Figure 18: Distribution of iron across the Motueka / Riwaka Plains from 2019 survey. The DWSNZ GV for iron is 0.20 g/m^3.

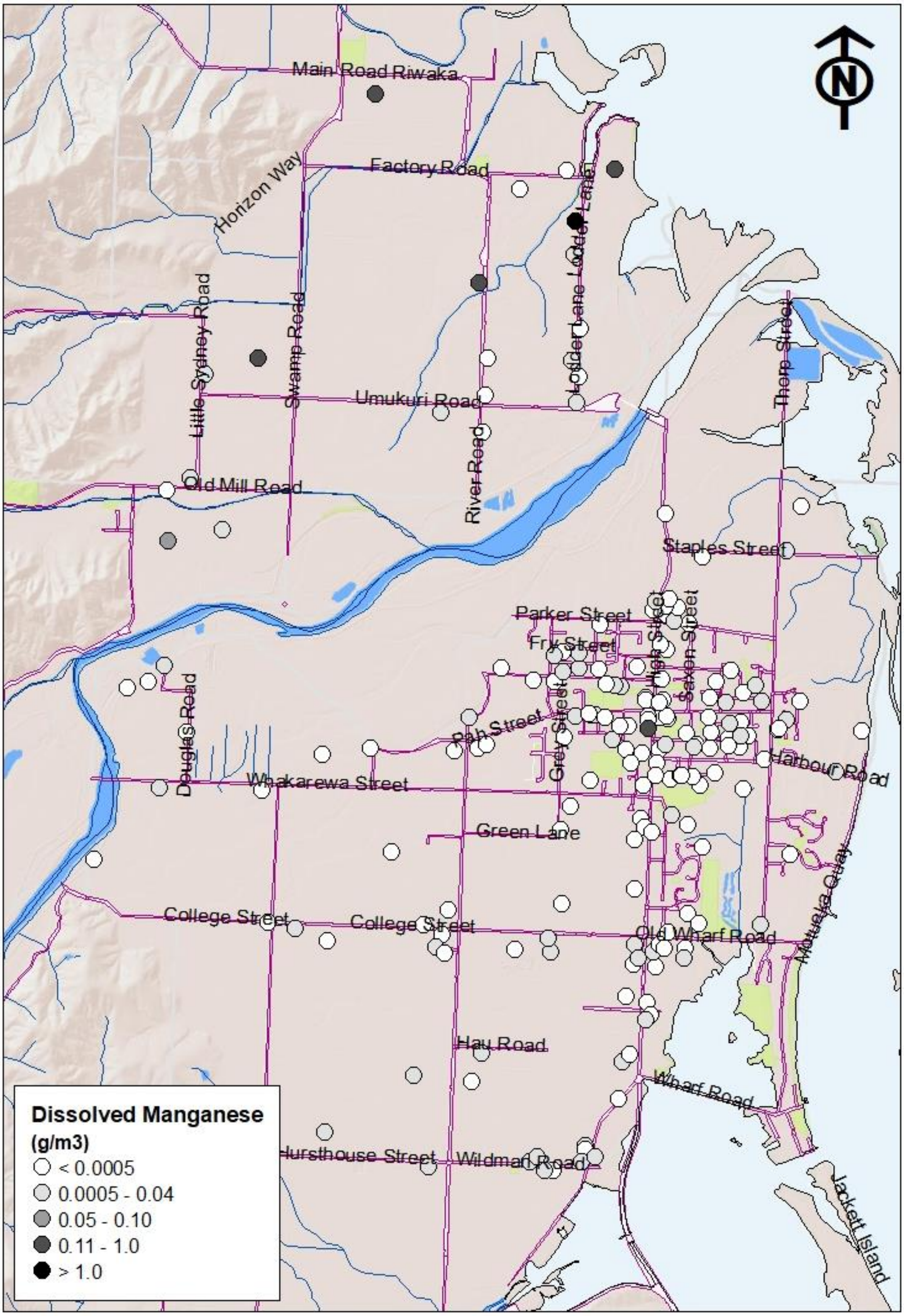


Figure 19: Distribution of manganese across the Motueka / Riwaka Plains from 2019 survey The DWSNZ GV for manganese is 0.04 g/m3 (staining of laundry), 0.10 g/m3 (taste threshold).

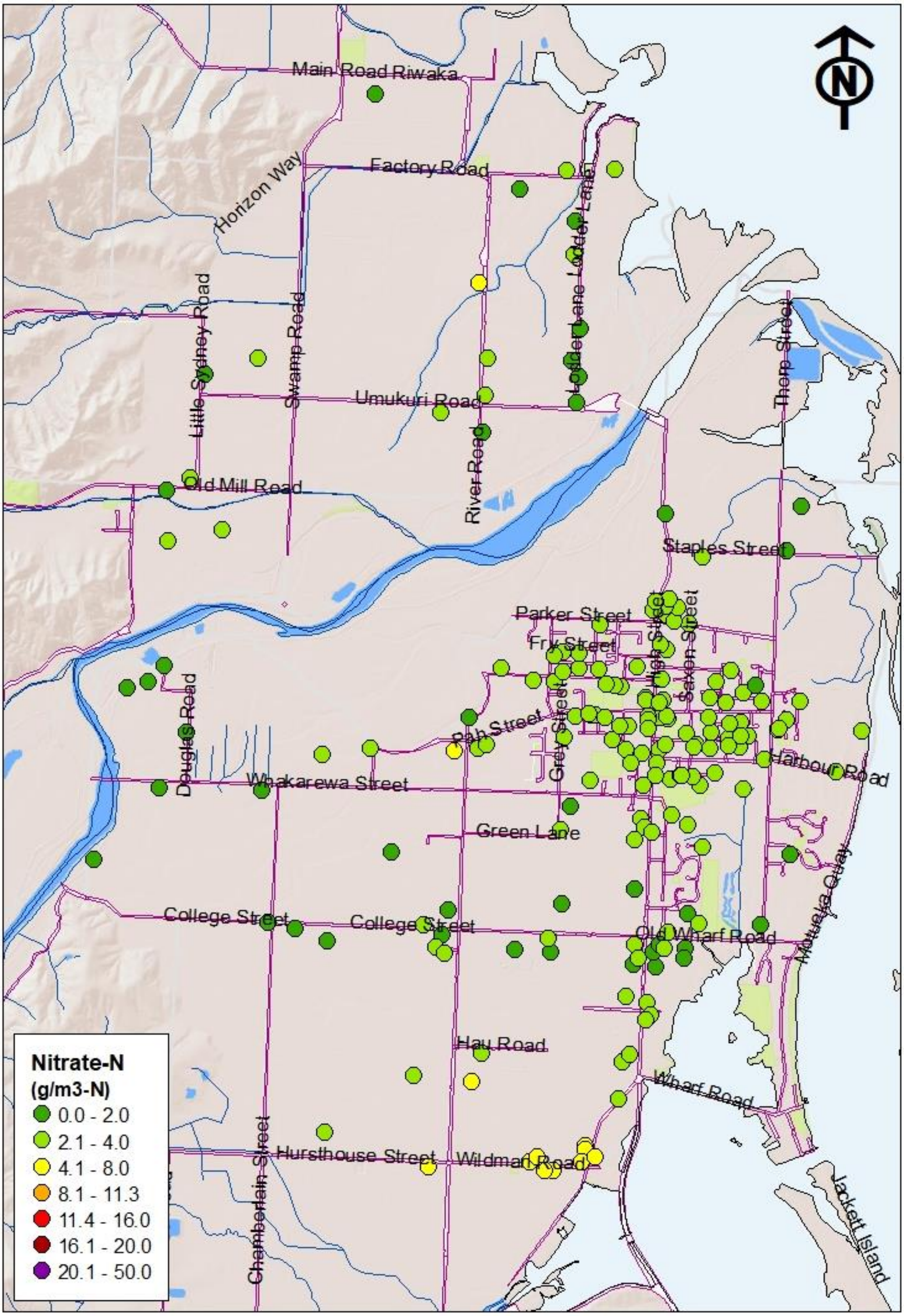


Figure 20: Distribution of nitrate-N across the Motueka / Riwaka Plains from 2019 survey. The DWSNZ MAV for nitrate-N is 11.3 g/m^3.

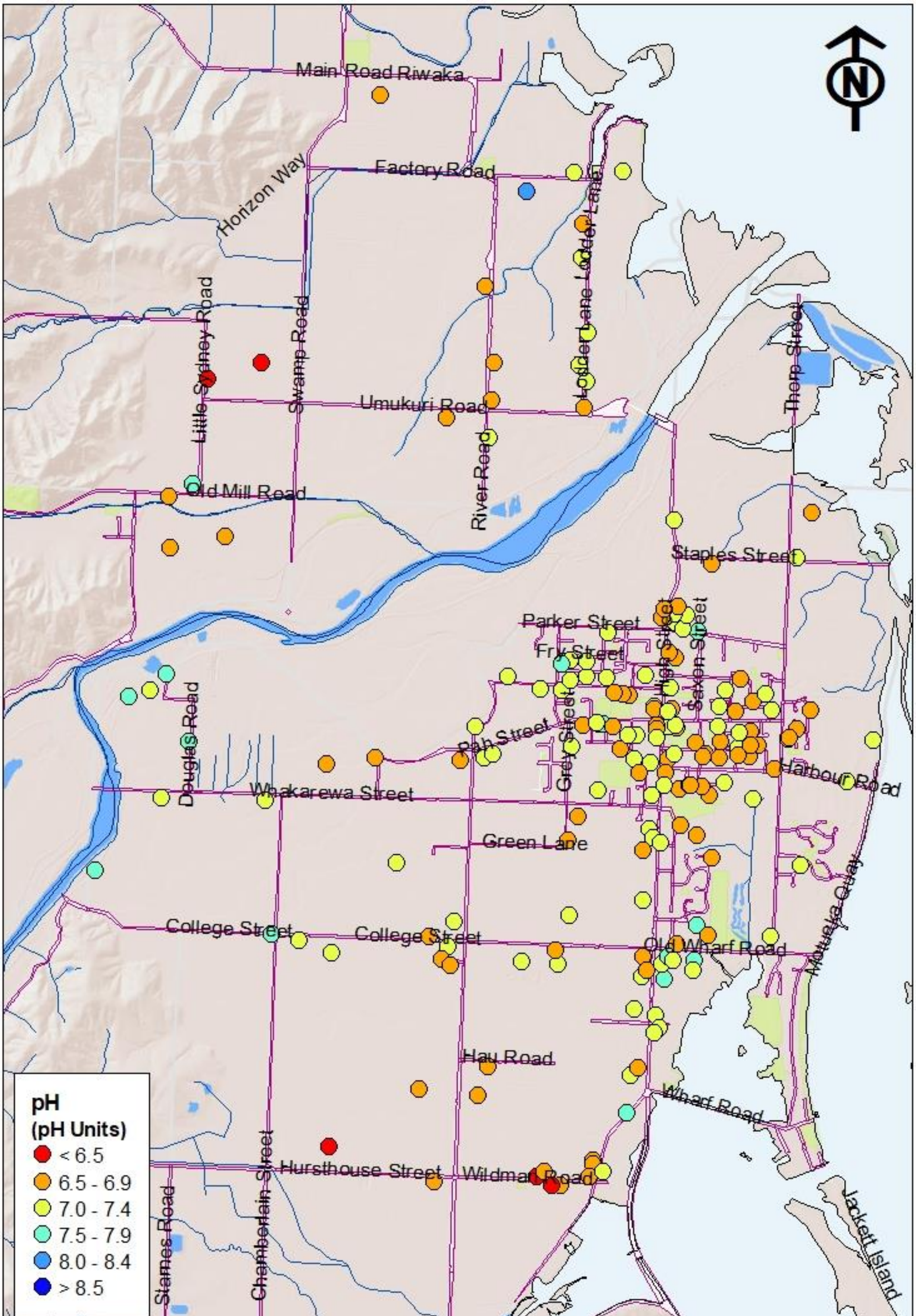


Figure 21: Distribution of pH across the Motueka / Riwaka Plains from 2019 survey. The DWSNZ GV for pH is between 7.0 – 8.5 pH units.

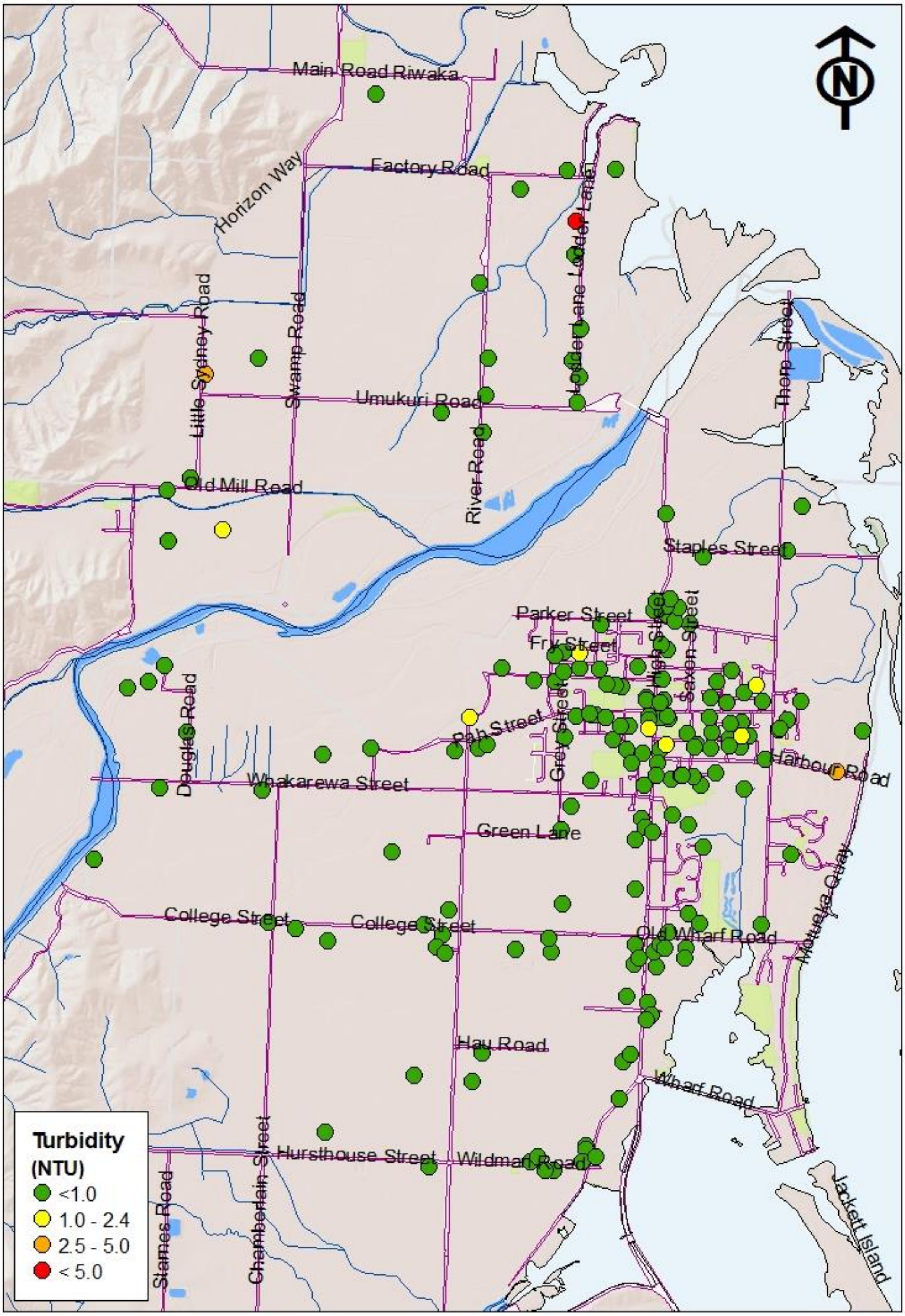


Figure 22: Distribution of turbidity across the Motueka / Riwaka Plains from 2019 survey. The DWSNZ GV for turbidity is 2.5 NTU.

Appendix III

Data from pervious synoptic surveys and SoE monitoring bores.

Historic data was plotted then fit with a linear trendline. Trends were identified when the gradient was large (either positive or negative), combined with a high r^2 value (coefficient of determination – the proportion of the variance in the dependent variable that is predictable from the independent variable. An r^2 of 1 means the data falls directly on the trendline, r^2 of 0 means utterly random scatter), and also a large difference of the 2019 sample result from the historic bore mean data.

Conductivity (µS/cm)

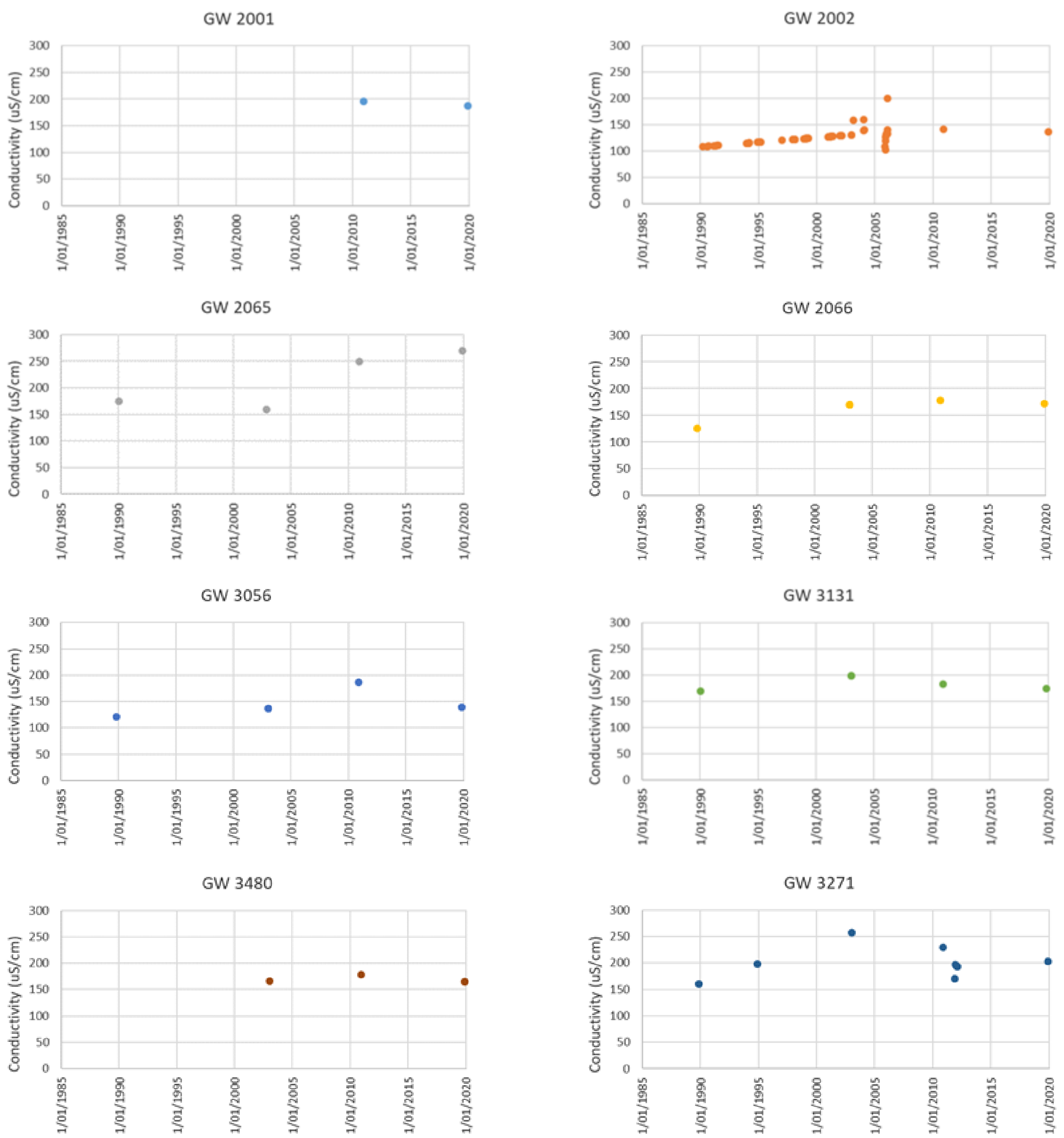


Figure 23: Measured conductivity data over time for Motueka / Riwaka Plains.

Table 5: Conductivity data analysis over time for Motueka / Riwaka Plains.

Conductivity	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	187.9	192.10	N/A	N/A	Unknown. 2 data points.
GW 2002	135.9	123.90	0.0043	0.3916	No significant trend
GW 2065	269.1	213.37	0.0099	0.7114	Potential slight increase
GW 2066	171.8	162.73	0.0042	0.6469	No significant trend
GW 3056	139.5	144.09	0.0031	0.2603	No significant trend
GW 3131	174.2	184.56	0.00007	0.0004	No significant trend
GW 3271	203	207.29	0.001	0.0096	No significant trend
GW 3480	165.2	169.67	N/A	N/A	Unknown. 3 data points.
GW 3393	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3115	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3216	N/A	N/A	N/A	N/A	Parameter not sampled
GW 23604	N/A	N/A	N/A	N/A	Parameter not sampled

Iron (g/m^3)

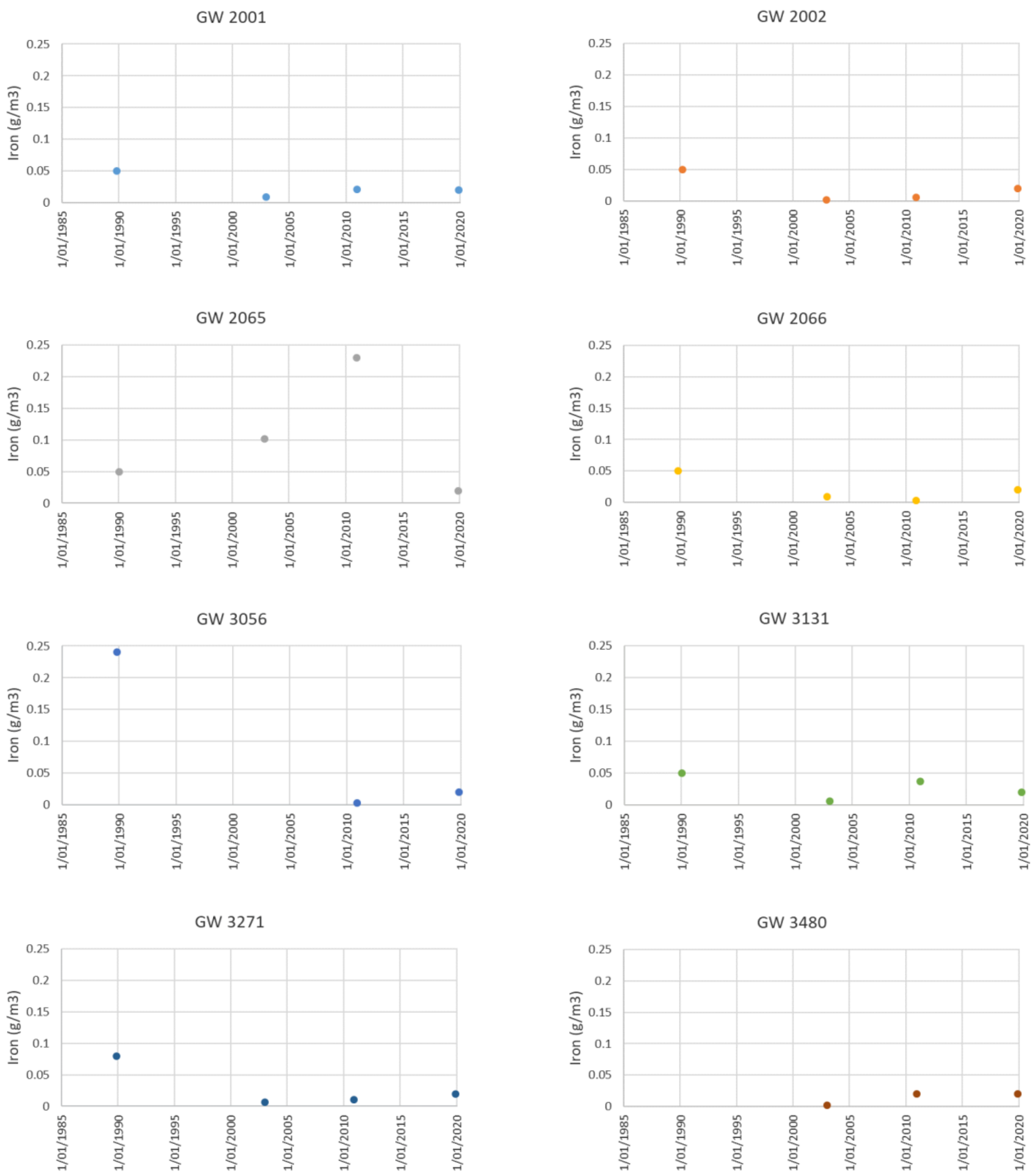


Figure 24: Measured iron concentrations over time for Motueka / Riwaka Plains.

Table 6: Iron data analysis over time for Motueka / Riwaka Plains.

Iron	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	< 0.02	0.03	-0.000002	0.4399	No significant trend
GW 2002	< 0.02	0.02	-0.000003	0.3521	No significant trend
GW 2065	< 0.02	0.10	0.000002	0.0085	No significant trend
GW 2066	< 0.02	< 0.02	-0.000003	0.4496	No significant trend
GW 3056	< 0.02	0.09	N/A	N/A	Unknown. 3 data points.
GW 3131	< 0.02	0.03	-0.000002	0.2311	No significant trend
GW 3271	< 0.02	0.03	-0.000005	0.5454	No significant trend
GW 3480	< 0.02	< 0.02	N/A	N/A	Unknown. 3 data points.
GW 3393	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3115	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3216	N/A	N/A	N/A	N/A	Parameter not sampled
GW 23604	N/A	N/A	N/A	N/A	Parameter not sampled

Manganese (g/m^3)

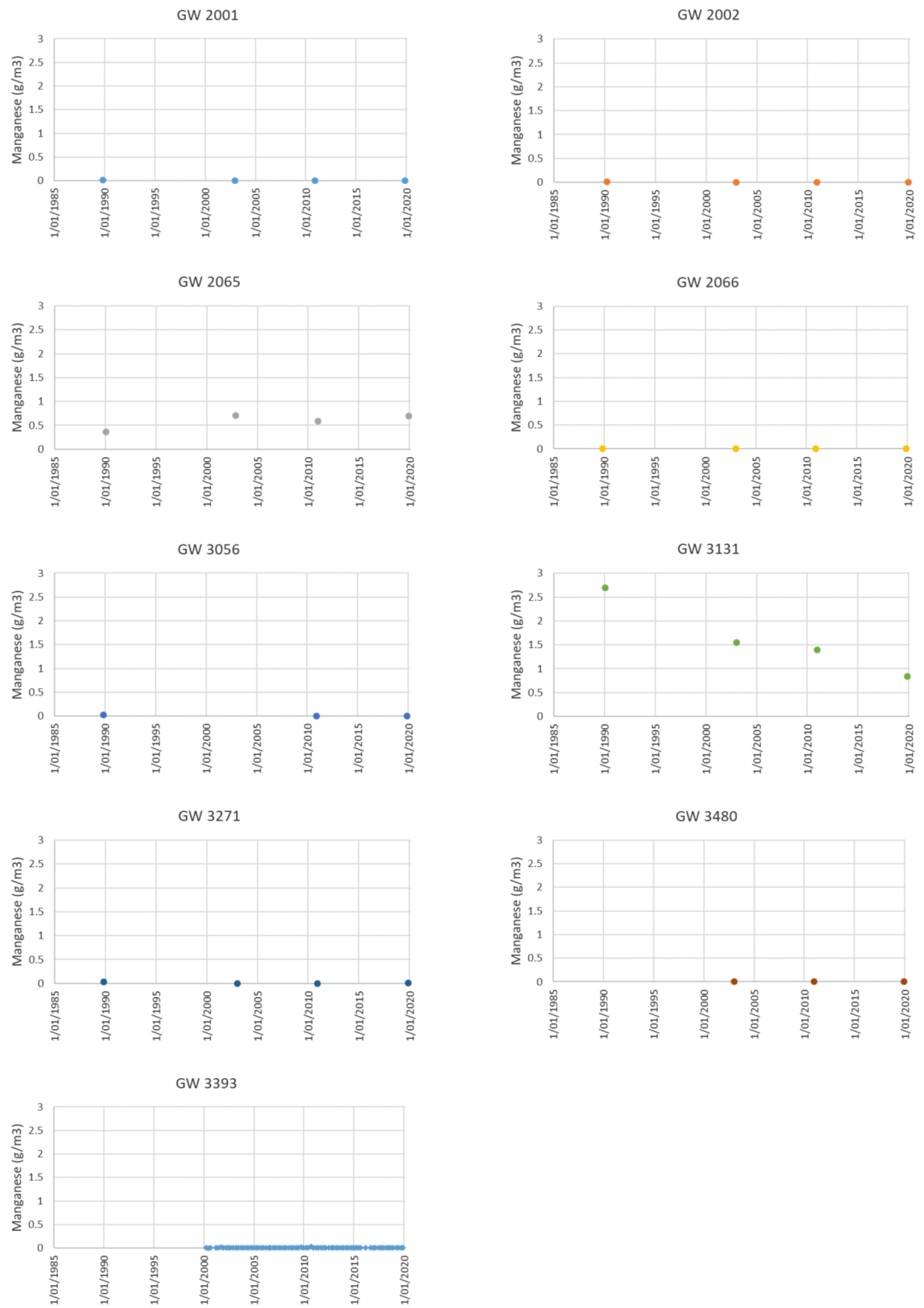
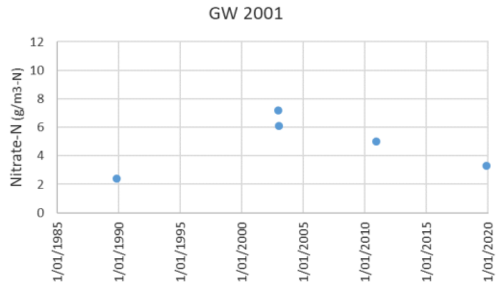


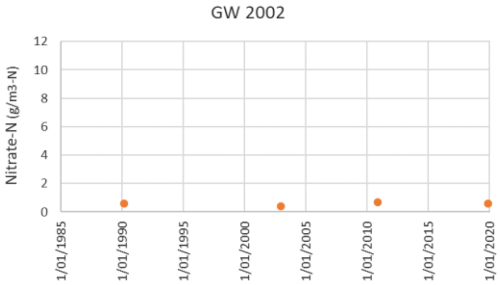
Figure 25: Measured manganese concentrations over time for Motueka / Riwaka Plains.

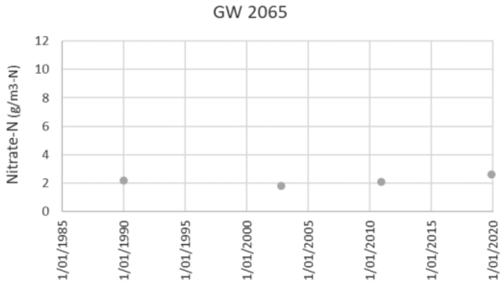
Table 7: Manganese data analysis over time for Motueka / Riwaka Plains.

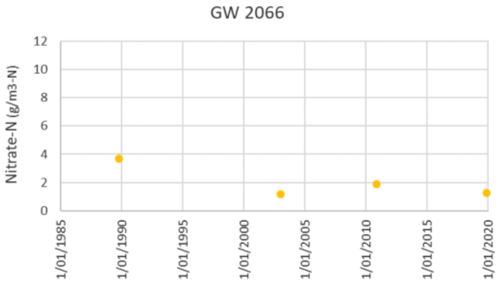
Manganese	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	< 0.0005	< 0.0005	N/A	N/A	Parameter not detected
GW 2002	< 0.0005	< 0.0005	N/A	N/Av	Parameter not detected
GW 2065	0.69	0.5878	0.00003	0.585	No significant trend
GW 2066	< 0.0005	< 0.0005	N/A	N/A	Parameter not detected
GW 3056	< 0.0005	< 0.0005	N/A	N/A	Parameter not detected
GW 3131	0.84	1.6225	-0.0002	0.953	Potential slight decrease
GW 3271	< 0.0005	< 0.0005	N/A	N/A	Parameter not detected
GW 3480	< 0.0005	< 0.0005	N/A	N/A	Unknown. 3 data points.
GW 3393	0.0069	0.01	-0.0000004	0.0473	No significant trend
GW 3115	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3216	N/A	N/A	N/A	N/A	Parameter not sampled
GW 23604	N/A	N/A	N/A	N/A	Parameter not sampled

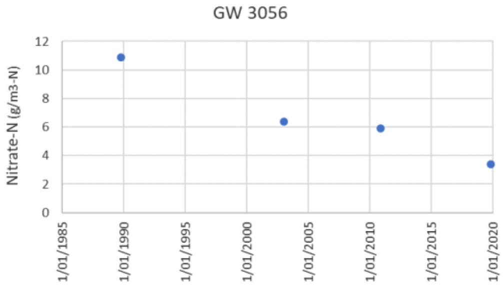
Nitrate-N (g/m^3)

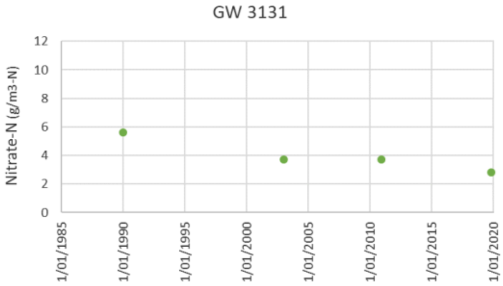


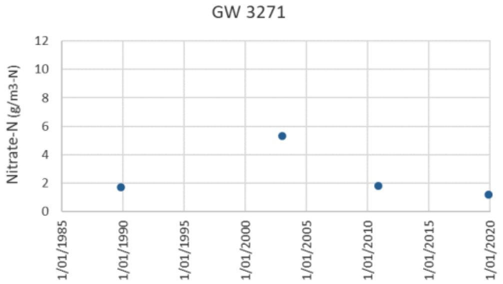


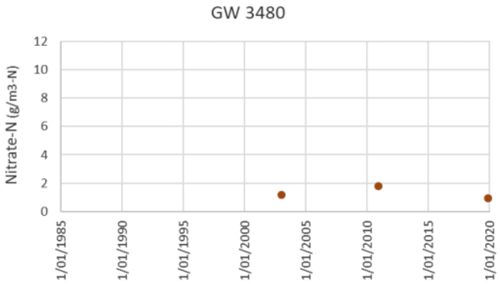


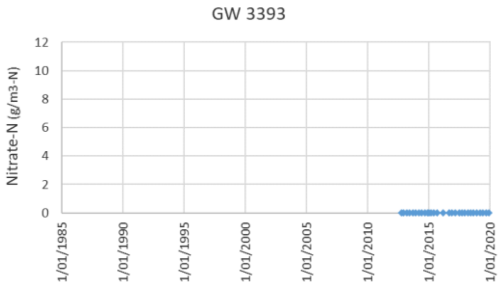


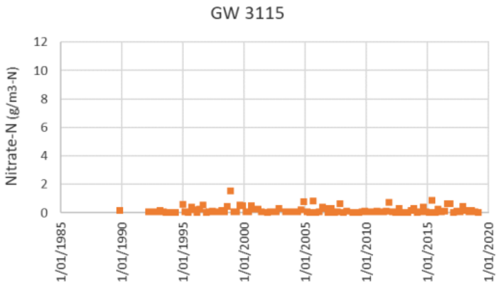












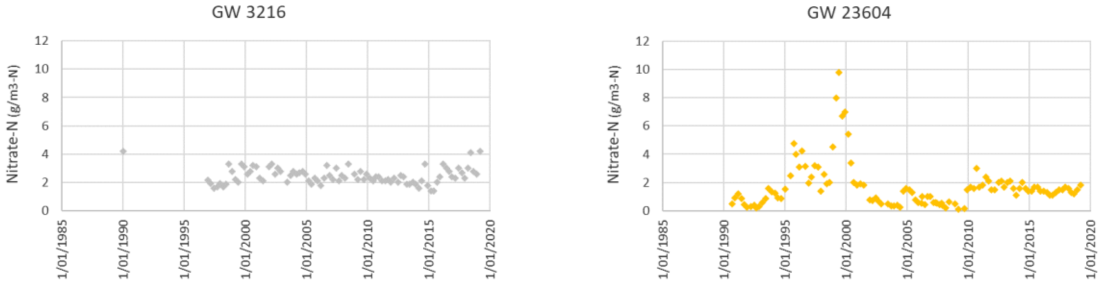
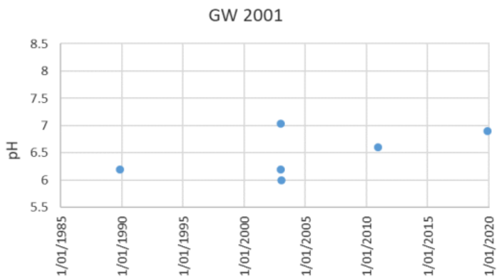


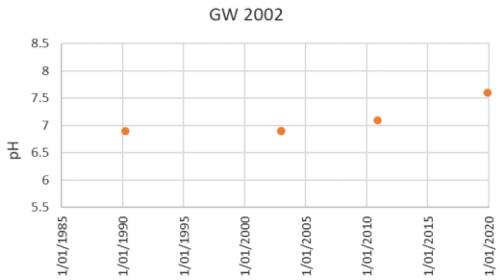
Figure 26: Measured nitrate-N concentrations over time for Motueka / Riwaka Plains.

Table 8: Nitrate-N data analysis over time for Motueka / Riwaka Plains.

Nitrate-N	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	3.3	4.80	0.00004	0.008	No significant trend
GW 2002	0.57	0.57	0.000004	0.0208	No significant trend
GW 2065	2.6	2.18	0.00004	0.2527	No significant trend
GW 2066	1.26	3.28	-0.0002	0.6467	No significant trend
GW 3056	3.4	6.65	-0.0007	0.9574	Potential slight decrease
GW 3131	2.8	3.95	-0.0002	0.913	No significant trend
GW 3271	1.21	2.50	-0.00009	0.0542	No significant trend
GW 3480	0.96	1.32	N/A	N/A	Unknown. 3 data points.
GW 3393	< 0.002	< 0.002	N/A	N/A	Parameter not detected
GW 3115	0.003	0.16	0.0000006	0.00005	No significant trend
GW 3216	4.2	2.47	-0.000001	0.0006	No significant trend
GW 23604	1.8	1.69	-0.00007	0.0171	No significant trend

pH (pH units)


GW 2001
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020


GW 2002
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
1/01/2000
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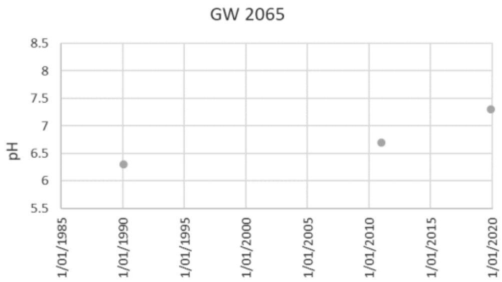
1/01/2010
1/01/2015
1/01/2020


GW 2065
pH
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8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
1/01/2000
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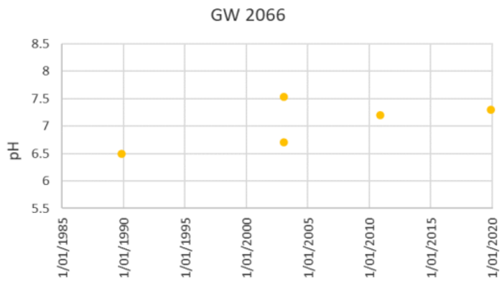
1/01/2010
1/01/2015
1/01/2020


GW 2066
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
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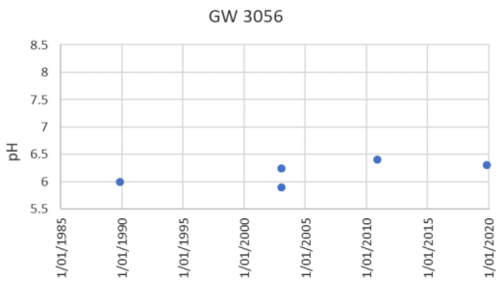
1/01/2015
1/01/2020


GW 3056
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
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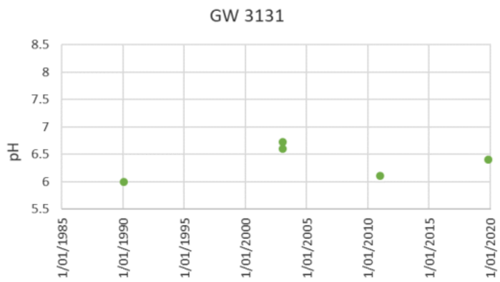
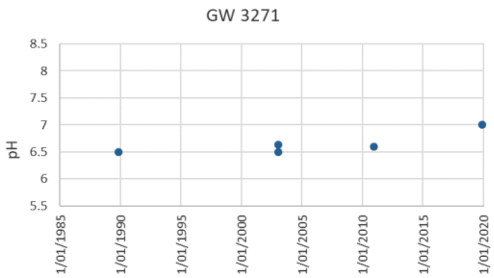
1/01/2010
1/01/2015
1/01/2020


GW 3131
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
1/01/2000
1/01/2005
1/01/2010
1/01/2015
1/01/2020


GW 3271
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
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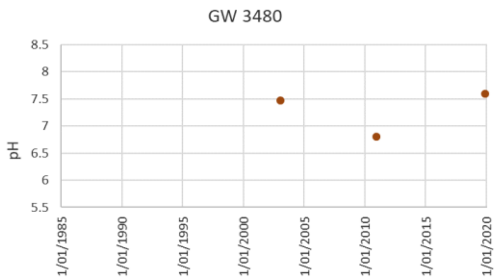
1/01/2015
1/01/2020


GW 3480
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
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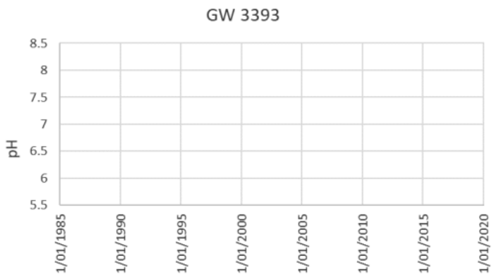
1/01/2010
1/01/2015
1/01/2020


GW 3393
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
1/01/2000
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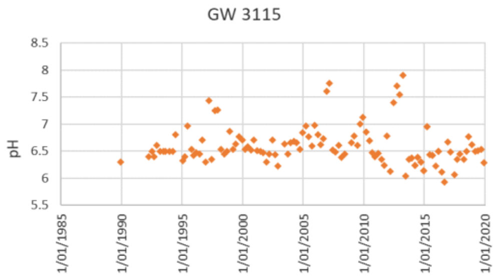
1/01/2010
1/01/2015
1/01/2020


GW 3115
pH
8.5
8
7.5
7
6.5
6
5.5
1/01/1985
1/01/1990
1/01/1995
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1/01/2015
1/01/2020

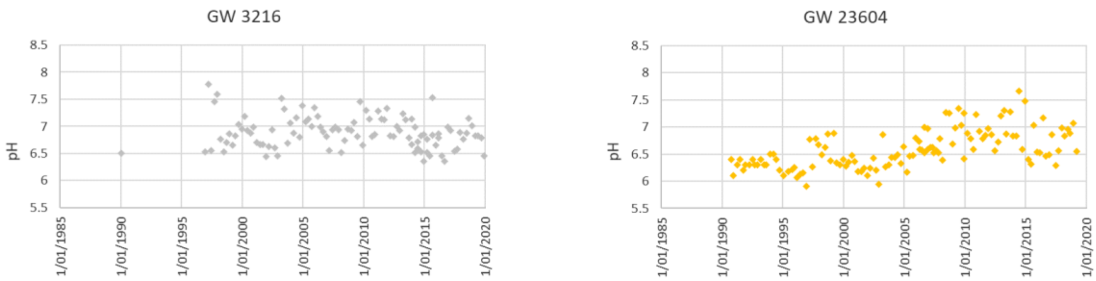


Figure 27: Measured pH data over time for Motueka / Riwaka Plains.

Table 9: pH data analysis over time for Motueka / Riwaka Plains.

pH	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	6.9	6.5	0.00006	0.3067	No significant trend
GW 2002	7.6	7.1	0.00006	0.7135	No significant trend
GW 2065	7.3	6.8	0.00008	0.8869	No significant trend
GW 2066	7.3	6.8	0.00007	0.4413	No significant trend
GW 3056	6.3	6.2	0.00003	0.4439	No significant trend
GW 3131	6.4	6.4	0.00002	0.0554	No significant trend
GW 3271	7	6.6	0.00004	0.6748	No significant trend
GW 3480	7.6	7.3	N/A	N/A	Unknown. 3 data points.
GW 3393	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3115	6.3	6.6	-0.00001	0.0084	No significant trend
GW 3216	6.5	6.9	-0.00002	0.0174	No significant trend
GW 23604	6.6	6.6	0.00007	0.3587	No significant trend

Sulphate (g/m^3)

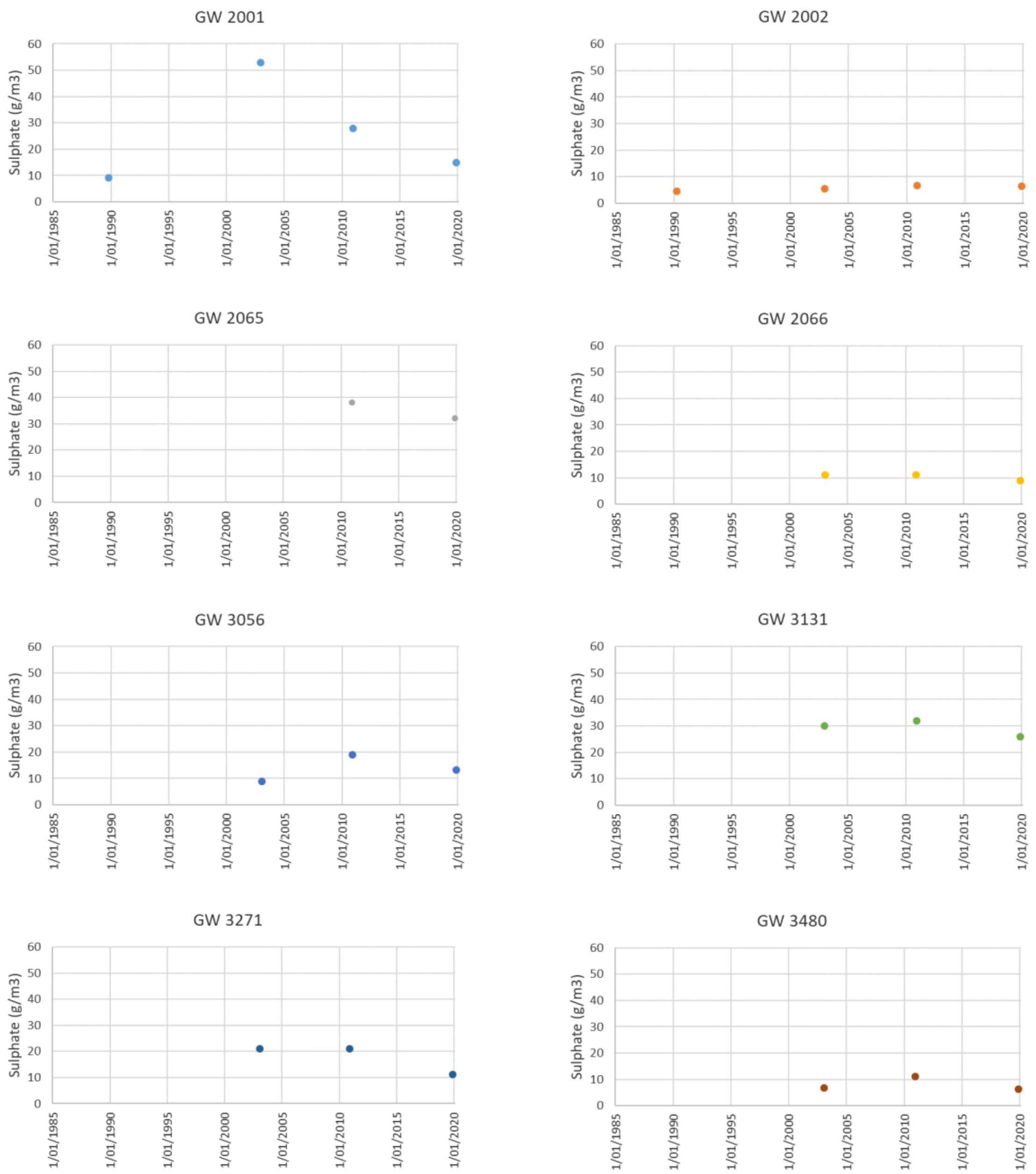
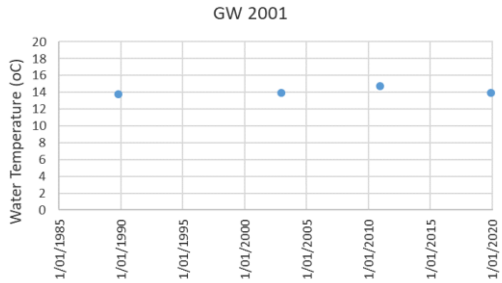


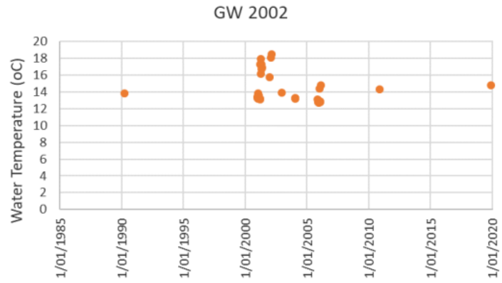
Figure 28: Measured sulphate concentrations over time for Motueka / Riwaka Plains.

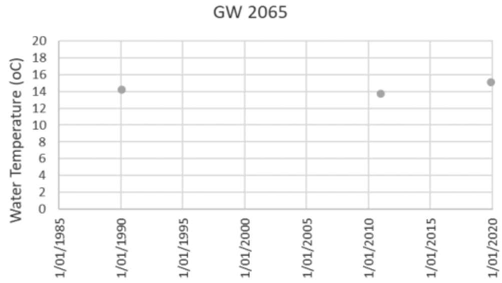
Table 10: Sulphate data analysis over time for Motueka / Riwaka Plains.

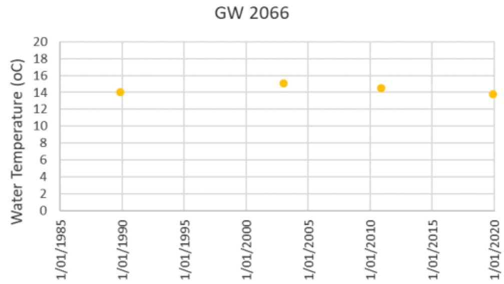
Sulphate	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	14.9	26.3	0.0003	0.0037	No significant trend
GW 2002	6.4	5.8	0.0002	0.8529	No significant trend
GW 2065	32	35.0	N/A	N/A	Unknown. 2 data points.
GW 2066	8.9	12.0	N/A	N/A	Unknown. 3 data points.
GW 3056	13.3	13.7	N/A	N/A	Unknown. 3 data points.
GW 3131	26	29.3	N/A	N/A	Unknown. 3 data points.
GW 3271	11.1	17.7	N/A	N/A	Unknown. 3 data points.
GW 3480	6.2	8.0	N/A	N/A	Unknown. 3 data points.
GW 3393	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3115	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3216	N/A	N/A	N/A	N/A	Parameter not sampled
GW 23604	N/A	N/A	N/A	N/A	Parameter not sampled

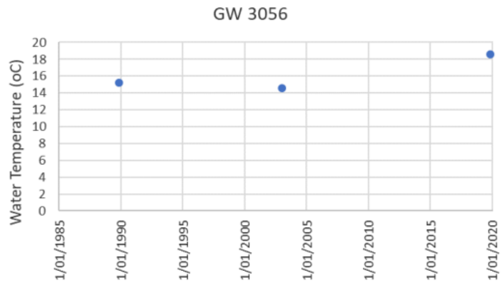
Temperature (ºC)

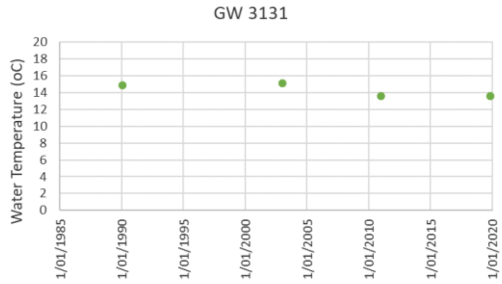


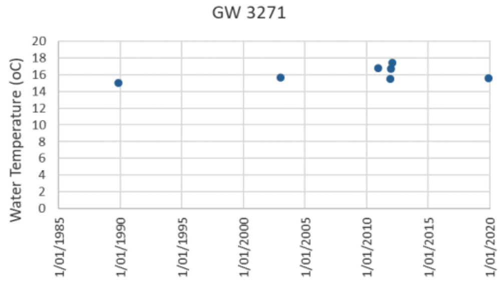


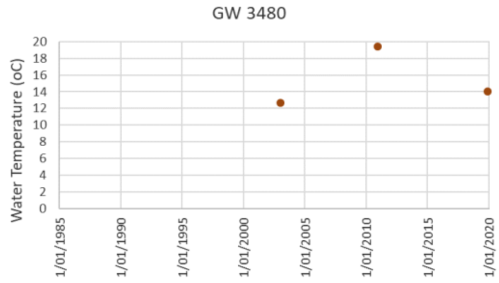


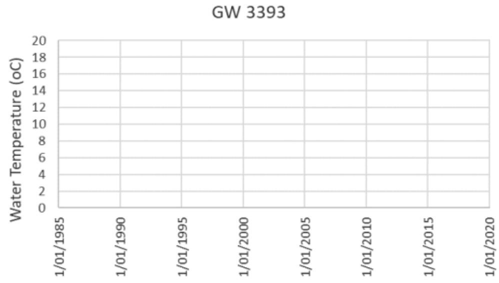


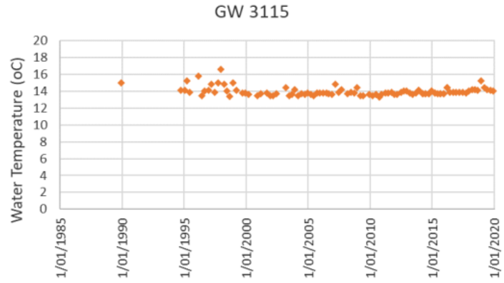












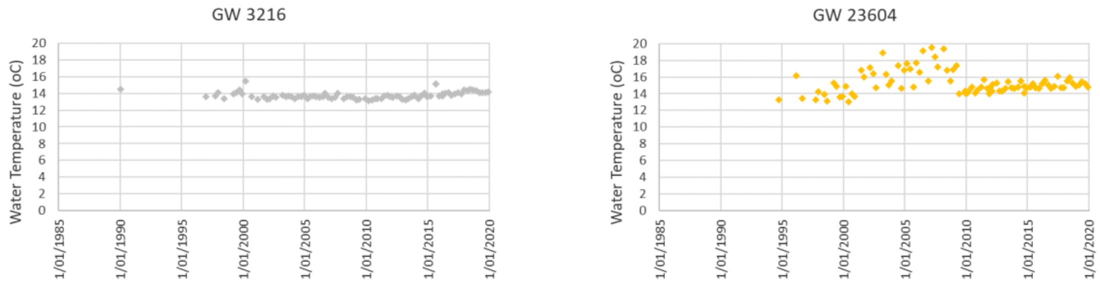


Figure 29: Measured temperature data over time for Motueka / Riwaka Plains.

Table 11: Temperature data analysis over time for Motueka / Riwaka Plains.

Temperature	2019 Result	Bore Mean	Gradient	r^2 Value	Trend
GW 2001	13.9	14.1	0.00003	0.1233	No significant trend
GW 2002	14.8	14.4	-0.0002	0.0272	No significant trend
GW 2065	15.1	14.3	N/A	N/A	Unknown. 3 data points.
GW 2066	13.8	14.5	-0.00002	0.0245	No significant trend
GW 3056	18.6	17.6	N/A	N/A	Unknown. 3 data points.
GW 3131	13.6	14.3	-0.0001	0.6648	No significant trend
GW 3271	15.6	16.1	0.0001	0.2205	No significant trend
GW 3480	14	15.4	N/A	N/A	Unknown. 3 data points.
GW 3393	N/A	N/A	N/A	N/A	Parameter not sampled
GW 3115	14	14.0	-0.00004	0.0547	No significant trend
GW 3216	14.2	13.8	0.00003	0.026	No significant trend
GW 23604	14.8	15.4	-0.00006	0.007	No significant trend

Appendix IV

The surface water (rivers and springs) were analysed using numerical attribute states for each water quality attribute for the protection of river ecosystem health, aesthetics and human health as detailed in Table 12. Attributes highlighted in blue are included in the National Policy Statement for Freshwater Management (NPSFM 2014). Table 12 shows only the attributes which correspond to the parameters tested for in the 2019 Motueka / Riwaka Plains groundwater quality survey. Dissolved oxygen and nitrate-N were compared against the most conservative range (lowest 1-day minimum and annual median respectively). N/A means not enough data or data not collected at those sites.

Table 12: Extract of surface water attributes from the Council State of the Environment Report for River Water Quality (Tasman District Council, 2015).

Attribute	Statistic	Units	Attribute State				Source
			A	B	C	D	
Dissolved oxygen concentration	7-day mean minimum	g/m^3	≥8	7 - 8	5 - 7	<5	NPSFM (2014)
	Lowest 1-day minimum	g/m^3	≥7.5	5 - 7.5	4 - 5	<4	
Dissolved reactive phosphorus	Single measurement	g/m^3	<0.01	≥0.01	N/A	N/A	ANZECC & ARMCANZ (2000)
E. coli	Annual median	MPN/100 mL	≤260	260 - 540	540 - 1000	>1000	NPSFM (2014)
	95th percentile	MPN/100 mL	≤260	260 - 540	540 - 1000	>1000	
Nitrate-N	Annual median	g/m3	≤1.0	1.0 - 2.4	2.4 – 6.9	>6.9	NPSFM (2014)
	Annual 95th percentile	g/m^3	≤1.5	1.5 - 3.5	3.5 - 9.8	>9.8	
pH	Single measurement	N/A	6.5 - 8.5	5 - 6.5, 8.5 - 9	>5 or >9	N/A	-
Turbidity	Single measurement	NTU	≤5.6	>5.6	N/A	N/A	ANZECC & ARMCANZ (2000)
Water Temperature	Midpoint of daily mean and daily maximum	^oC	≤18	18 - 20	20 - 24	>24	Davies-Colley et al. (2013)

Table 13: River water quality for the 2019 Motueka / Riwaka Plains groundwater survey.

River	Dissolved Oxygen (g/m³)		Dissolved Reactive Phosphorus (g/m³)		*E.coli* (MPN/100 mL)		Nitrate-N (g/m³)		pH		Turbidity (NTU)		Water Temperature (°C)	
	2019 Result	River Median	2019 Result	River Median	2019 Result	River Median	2019 Result	River Median	2019 Result	River Median	2019 Result	River Median	2019 Result	River Median
RW Brooklyn @ Westbank Rd	12.58	11.82	0.0195	N/A	58	58	0.043	N/A	8.52	7.57	1.32	3.45	13.0	12.7
RW Motueka @ Woodmans Bend	11.87	11.65	<0.001	0.005	12	15	0.102	0.110	8.58	7.99	0.54	0.70	18.9	12.4
RW Riwaka @ Riwaka Vly Rd	11.59	N/A	0.0061	0.007	49	N/A	0.153	0.101	8.28	8.21	0.82	N/A	16.3	N/A
RW Little Sydney @ Settlers Rd Bridge	11.60	N/A	0.023	N/A	162	N/A	0.056	N/A	8.31	N/A	1.22	N/A	14.2	N/A
RW Woodlands Drain 550m us Old Wharf Rd	8.34	N/A	0.0179	N/A	387	N/A	1.7	N/A	7.07	N/A	2.20	N/A	12.3	N/A
Average (excluding Woodlands Stream)	11.91	11.74	0.016	0.006	70	36.5	0.089	0.106	8.42	7.92	0.98	2.075	15.6	12.6

Table 14: Spring water quality for the 2019 Motueka / Riwaka Plains groundwater survey.

Spring	Dissolved Oxygen (g/m³)		Dissolved Reactive Phosphorus (g/m³)		*E.coli* (MPN/100 mL)		Nitrate-N (g/m³)		pH		Turbidity (NTU)		Water Temperature (°C)	
	2019 Result	Spring Median	2019 Result	Spring Median	2019 Result	Spring Median	2019 Result	Spring Median	2019 Result	Spring Median	2019 Result	Spring Median	2019 Result	Spring Median
GW Thorp Spring @ Old Wharf Rd	N/A	N/A	0.0027	N/A	111	N/A	1.50	N/A	6.35	N/A	1.05	N/A	16.2	N/A
GW Frys Spring @ Lodder Lane	N/A	N/A	0.0091	N/A	117	N/A	1.12	N/A	6.45	N/A	1.21	N/A	19.1	N/A
GW Spring @ Thorp Fearon Cnr	N/A	N/A	0.0127	N/A	345	N/A	1.74	N/A	6.36	N/A	1.79	N/A	16.5	N/A
GW Spring at Ingils	N/A	N/A	0.0151	N/A	133	N/A	0.45	N/A	6.77	N/A	1.22	N/A	13.8	N/A
GW Staples St Spring at Culvert	N/A	N/A	0.0053	N/A	121	N/A	1.08	N/A	6.51	N/A	0.25	N/A	14.1	N/A
Average	N/A	N/A	0.0090	N/A	165	N/A	1.18	N/A	6.49	N/A	1.10	N/A	15.9	N/A