Groundwater quality in the Wellington region

State and trends

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REGIONAL COUNCIL
Te Pane Matua Taiao

Groundwater quality in the Wellington region

State and trends

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Main cover photo: Groundwater flowing from an open hydrant during purging of a bore in the Wairarapa

Executive summary

To assist with the sustainable management of groundwater resources in the Wellington region, Greater Wellington carries out quarterly State of the Environment (SoE) monitoring of groundwater quality at 71 sites. This report provides a comprehensive assessment of the results of this monitoring, looking at both state and trends in groundwater quality over the five-year period ending 31 July 2010. The state assessment includes the use of water quality indices to summarise the suitability of the region's groundwater for potable use and the potential for toxicity-related impacts of groundwater discharge to surface water ecosystems. The report also includes information from recent targeted groundwater quality investigations.

Principal Component Analysis (PCA) indicates that groundwater chemistry in the Wellington region is strongly influenced by natural factors, principally redox potential and rock-water interaction, as well as human activity. Hierarchical Cluster Analysis (HCA) assigned the 71 Groundwater Quality SoE (GQSOE) bores into two main hydrochemical clusters; one characterised by oxygen-rich groundwater sourced from rainfall recharge and/or river drainage from unweathered greywacke, and another that is typical of river drainage from weathered greywacke and/or groundwater that is influenced by oxygen-poor conditions.

Median values drawn from GQSoE data collected quarterly between August 2005 and July 2010 indicate that groundwater quality in the Wellington region is generally very good, particularly from a drinking water perspective. Iron and manganese were the main two variables to exceed DWSNZ (2005) thresholds, but these exceedences were generally limited to non-potable bores located in semi-confined to confined oxygen-poor aquifers that naturally exhibit elevated concentrations of these elements. Positive *E. coli* counts were recorded on at least one sampling occasion in 26 bores, six of which are used for potable supply. Some of this contamination may reflect poor bore/wellhead protection rather than the quality of the underlying groundwater quality. However, one bore at Te Horo Beach on the Kapiti Coast consistently recorded *E. coli* counts well in excess of the DWSNZ (2005) MAV and water quality in this bore is clearly impacted by land use at the site.

Surveys undertaken in 2006 and 2010 indicate there is limited pesticide and herbicide contamination of groundwater in the Wellington region. Similarly, a one-off assessment of heavy metals and metalloids in March 2009 found no significant contamination issues other than identifying a relatively widespread presence of arsenic which is consistent with natural rock-water interaction.

Temporal trend analyses performed across 10 water quality variables revealed a relatively small proportion (7.6%) of environmentally meaningful trends (ie, statistically significant and a relative rate of change >5%/year, or an absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr). The majority of these trends were associated with just four variables: dissolved manganese (11), dissolved iron (8), dissolved reactive phosphorus (DRP, 9) and nitrate nitrogen (8). Further, over half (58%) of the environmentally meaningful trends reflected decreases in the concentration of a specific water quality variable and, therefore, can be considered representative of improving trends.

While the Drinking Water Quality Index (WQI) classified 75% of the 71 GQSoE bores as being ‘good’ or ‘excellent’ for potable use, the Aquatic Ecosystems WQI showed that just 49% of the bores were ‘good’ or ‘excellent’, a reflection of the lower thresholds used to assess aquatic toxicity, particularly for nitrate nitrogen (nitrate) and zinc. In the case of nitrate, none of the 71 GQSoE bores recorded a median concentration above the DWSNZ (2005) MAV but, in 23 bores, the median exceeded the recommended aquatic ecosystems toxicity threshold of 1.7 mg/L. Of these 23 bores, 17 are located in unconfined to semi-confined aquifers where there is an increased likelihood of discharge to surface water. While strong evidence exists that discharge of nitrate-enriched groundwater is impacting on surface water quality in the Mangatarere and Parkvale Stream catchments near Carterton, potential impacts from nitrate-enriched groundwater discharge in other catchments in the Wellington region are largely unknown. With further land use intensification expected in the region in the future (eg, in some parts of the Wairarapa) and long time lags often associated with groundwater entering surface water, it is critical that best practice land management practices are implemented to minimise adverse impacts on underlying groundwater and connected surface water resources. Continued monitoring of soil, groundwater and surface water quality is also needed.

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1. Introduction

Groundwater in the Wellington region is used extensively for potable and stock supply, irrigation and industry. Groundwater also provides baseflow to rivers, streams and wetlands, or forms natural springs or seeps where it discharges at the ground's surface. The protection of these surface water ecosystems requires careful management of the quality and quantity of the underlying groundwater.

To assist with the sustainable management of groundwater resources in the Wellington region, Greater Wellington Regional Council (Greater Wellington) conducts regular monitoring of groundwater levels and quality. This report focuses solely on groundwater quality, providing a comprehensive assessment of the results of routine state of the environment groundwater quality monitoring undertaken over the five-year period ending 31 July 2010. Monitoring the state of the environment is a specific requirement for regional councils under Section 35(2)(a) of the Resource Management Act (RMA) 1991.

1.1 Report purpose

This technical report is one of eight covering air, land and water resources prepared with the primary purpose of informing the review of Greater Wellington's five regional plans. These plans were established to sustainably manage the region's natural resources, including groundwater. The review of the regional plans follows the recently completed review of the overarching Regional Policy Statement (RPS) for the Wellington region (GWRC 2010).

The focus of the eight technical reports is on providing an up-to-date analysis of monitoring information on state and trends in resource health as opposed to assessing the effectiveness of specific policies in the existing RPS (WRC 1995) or regional plans. Policy effectiveness reports were prepared in 2006 following the release of Greater Wellington's last formal State of the Environment (SoE) report, *Measuring up* (GWRC 2005).

The last technical report on state and trends in the region's groundwater resources was prepared by Jones and Baker (2005); this report focussed on both groundwater levels and quality over the period 1993 to 2005[1].

1.2 Report scope

This report presents a comprehensive assessment of state and trends in groundwater quality across the Wellington region, based on the results of routine quarterly monitoring at 71 sites over the period August 2005 to 31 July 2010. The report also includes information from recent targeted groundwater quality investigations.

Refer to Keenan et al. (2012) for a comprehensive analysis of state and trends in relation to groundwater allocation and levels.

[1] Greater Wellington also prepares annual summary reports documenting SoE monitoring results obtained in the last financial year. Refer to Tidswell et al. (2010) for the most recent annual groundwater monitoring report.

1.3 Report outline

The report comprises seven sections:

- Section 2 provides a brief overview of Greater Wellington's groundwater quality monitoring network, sampling methods and water quality indicators.
- Section 3 briefly outlines groundwater resources in the Wellington region, including the key natural and anthropogenic factors that can influence groundwater quality.
- Section 4 presents a detailed analysis of the current state of groundwater quality across the Wellington region. Spatial patterns in groundwater chemistry are outlined first, followed by a summary of overall groundwater quality in relation to relevant standards and guidelines for nine key indicator variables. Water quality indices are also presented to summarise the suitability of natural groundwater for potable use and for discharge to surface water ecosystems.
- Section 5 presents temporal trends in groundwater quality across the Wellington region over August 2005 to July 2010, focusing largely on the same principal indicator variables presented in Section 4.
- Section 6 discusses the main findings from Sections 4 and 5 and places these in a national context. The need to consider interactions between surface water and groundwater is discussed, and monitoring limitations and knowledge gaps are also outlined.
- Section 7 presents conclusions and recommendations.

1.4 Terminology and definitions

In some parts of this report, particularly in tables and figures, the names of some water quality variables and guideline documents have been abbreviated. Generally, the names are mentioned in full on their first use in each section. The principal abbreviations used in the report are listed in Table 1.1.

Table 1.1: List of main abbreviations used in this report

Abbreviation	Definition	Abbreviation	Definition
DRP	Dissolved reactive phosphorus	ANZECC	Australia and New Zealand Environment and Conservation Council
E. coli	*Escherichia coli*	TV	Trigger Value (in relation to ANZECC)
F	Fluoride	DWSNZ	Drinking Water Standards New Zealand
Fe	Iron	GV	Guideline Value (in relation to DWSNZ)
Mn	Manganese	MAV	Maximum Acceptable Value (in relation to DWSNZ)
NH_4-N / ammonia	Ammoniacal nitrogen	MfE	Ministry for the Environment
NO_2-N / nitrite	Nitrite nitrogen	HCA	Hierarchical cluster analysis
NO_3-N / nitrate	Nitrate nitrogen	PCA	Principal component analysis
Pb	Lead	GQSoE	Groundwater Quality State of the Environment
TDS	Total dissolved solids	SoE	State of the Environment

2. Overview of groundwater quality monitoring in the Wellington region

2.1 Background

Groundwater quality has been routinely monitored in the western half of the Wellington region (Kapiti Coast and Hutt Valley) since 1994 and in the Wairarapa since 1997. Up until 2003, this monitoring was effectively conducted under two separate programmes[2], with some differences present in the suite of water quality variables and the laboratory analytical methods employed. From late 2003 onwards, management practices were aligned to provide more consistency in sampling methods, sampling frequency (increased from six-monthly to quarterly), analysis and reporting. At this time, a number of changes were made to the location of monitoring sites, the range of variables monitored and the methods of analysis to improve the representativeness and quality of the information collected (see Appendix 1 for details).

Sites in the Groundwater Quality SoE (GQSoE) monitoring programme were selected based on bore location, depth, groundwater management zone (refer Section 3.2) and suitability for sampling. Refer to Appendix 1 for the complete list of site selection criteria and a summary of key changes to the monitoring programme.

2.2 Monitoring objectives

The aims of Greater Wellington's groundwater quality monitoring programme were first outlined by Cussins (1996) and Butcher (1997). Broadly speaking, the objectives were similar to those of the current programme:

- To provide information on the current state of groundwater quality;
- To assist in the detection of spatial and temporal changes in groundwater quality;
- To provide chemical analysis of groundwater to support conceptualisation of groundwater flow models and resource definition;
- To recommend the suitability of groundwater for designated uses; and
- To provide a mechanism to determine the effectiveness of regional policies and plans.

2.3 Monitoring sites and frequency

The existing GQSoE monitoring network consists of 71 bores (Figure 2.1; Appendix 1); 22 of these are located in the western part of the region (Kapiti and the Hutt Valley) and 49 in the eastern part (Wairarapa). Sampling of each bore is conducted at quarterly intervals (generally in March, June, September and December).

[2] Groundwater sampling and laboratory testing were managed separately from Greater Wellington's (then the Wellington Regional Council) Wellington and Masterton offices.

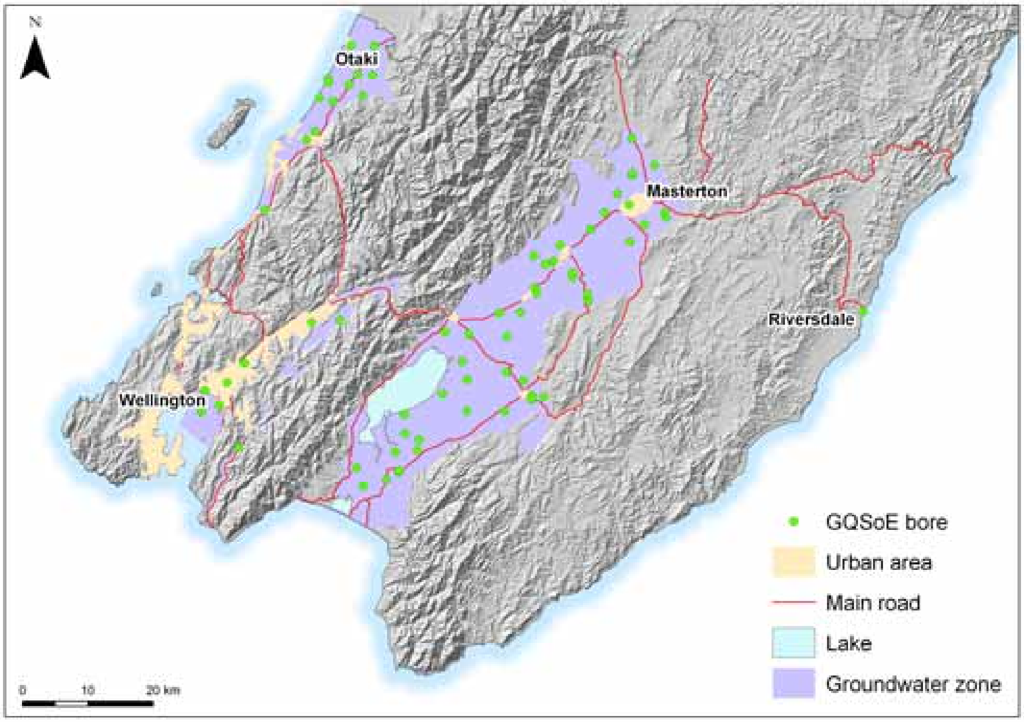

Figure 2.1: Location of the 71 groundwater bores in Greater Wellington's existing GQSoE monitoring network

2.4 Monitoring variables and methods

Groundwater quality is assessed by measuring 31 different variables, including pH, conductivity, turbidity, faecal indicator bacteria, total organic carbon, and dissolved nutrients and major ions (Table 2.1). The rationale for monitoring these variables, together with details of field measurements and analytical methods, is provided in Appendix 2. Groundwater samples are collected in accordance with nationally accepted protocols (Ministry for the Environment 2006).

As part of the quality assurance processes observed by Greater Wellington and its contracted analytical laboratory, the ion balance error associated with each groundwater sample tested is reported along with the overall results. Theoretically the ion balance error is 0% on the basis that the ionic strength of the anions and cations balances. In practical terms, acceptable values for an ion balance error are in the range ±5% (Freeze & Cherry 1979; Hem 1985; Daughney 2007), although for waters of low ionic strength values in the range ±10% can be acceptable (Fritz 1994). Greater Wellington's contracted analytical laboratory re-analyses any GQSoE sample with an ion balance error outside of the ±5% range.

Table 2.1: Physico-chemical and microbiological variables measured in Greater Wellington's GQSoE monitoring programme

Chemical tests	Variable	History of monitoring
Bacteria	Faecal coliforms *Escherichia coli* (*E. coli*)	Since July 1994 in the western region and November 1997 in the Wairarapa. Region-wide since October 2003
Major ions	Dissolved sodium Dissolved potassium Dissolved calcium Dissolved magnesium Chloride Sulphate Total alkalinity	Dissolved forms of sodium, potassium, calcium and magnesium region-wide since October 2003. Chloride, sulphate and total alkalinity since July 1994 in the western region and November 1997 in the Wairarapa.
Nutrients	Total ammoniacal nitrogen Nitrite-nitrate nitrogen (NNN) Nitrate nitrogen Nitrite nitrogen Dissolved reactive phosphorus (DRP)	Since July 1994 in the western region and November 1997 in the Wairarapa except NNN (region-wide since October 2003).
Metals[1]	Dissolved iron Dissolved manganese Dissolved lead Dissolved zinc	Region-wide since October 2003.
Trace elements	Bromide Fluoride Dissolved boron	Since July 1994 in the western region and since October 2003 in the Wairarapa.
Other	pH [2] Temperature Electrical conductivity (EC)[2] Dissolved oxygen (DO) Dissolved reactive silica (DRS) Total organic carbon (TOC)	Temperature, pH and EC since July 1994 in the western region and since November 1997 in the Wairarapa. DO since September 2000 in the western region and since March 2003 in the Wairarapa. DRS and TOC region-wide since October 2003.
Calculations	Total dissolved solids (TDS) Free carbon dioxide (CO_2) Bicarbonate (H_2CO_3) Total hardness Total anions Total cations % Difference in ion balance	TDS since July 1994 in the western region and since October 2003 in the Wairarapa. CO_2 since July 1994 in the western region and since November 1997 in the Wairarapa. H_2CO_3 since September 1996 in the western region and since November 1997 in the Wairarapa. Total hardness since July 1994 in the western region and since October 2003 in the Wairarapa. Total anions, total cations and ion balance region-wide since October 2003.

[1] Groundwater samples are also tested for dissolved arsenic, chromium, cadmium, nickel and copper but not on a routine basis.
[2] Conductivity and pH are tested in both the field and the laboratory.

2.5 Data used in this report

Analysis of state and temporal trends in groundwater quality across the region (Sections 4 and 5 of this report, respectively) has been limited to GQSoE data collected over the period 1 August 2005 to 31 July 2010 inclusive[3]. The principal reasons for this are:

- The sites monitored as part of the GQSoE programme have been relatively unchanged since mid 2005 (see Appendix 1);
- Sampling frequency and analytical methods have remained consistent since 2005 (and with no change in analytical laboratory); and
- This period was a logical follow-on from the 1993 to 2005 reporting period used in the last groundwater SoE technical report (Jones & Baker 2005).

2.5.1 Approach to analysis

Details on the methods used to analyse groundwater quality state and trends are outlined in Sections 4 and 5 respectively. Although this report focuses on routine GQSoE monitoring data collected over 2005 to 2010, results from the following programmes are also drawn on to assist with characterising the 'state' of groundwater quality across the region:

- National Groundwater Monitoring Programme (NGMP) – groundwater samples from 15 GQSoE bores are submitted quarterly to GNS Science for analysis (Greater Wellington has participated in the NGMP since 1994).
- Environmental Science and Research's (ESR) national pesticide monitoring programme – groundwater at selected sites throughout the region are tested for pesticides on a four-yearly basis (Greater Wellington has participated in four of the five national surveys to date providing groundwater samples in 1994 (five bores sampled), 1998 (10 bores), 2002 (12 bores), 2006 (17 bores) and 2010 (13 bores).
- Greater Wellington's targeted groundwater quality investigations, focusing principally on nutrient contamination, conducted in selected locations in the Wairarapa (reported in Tidswell 2008 and Milne et al. 2010) and the northern Kapiti Coast (reported in Tidswell 2009).

2.5.2 Data checks, processing and presentation

In addition to screening GQSoE sample results for the presence of potential outliers, the ion balance errors were assessed across all sample results collected over the five-year reporting period. A total of 1,198 (87.1%) samples had an ion balance error within the ±5% range; the remainder of samples had an ion balance error within ±15%. Overall, the ion balance error results give a high degree of confidence in the results of groundwater analysis (with respect to ionic compounds) and so the decision was made that no data would be excluded from the state or temporal trend analyses based on ion balance error.

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3 The intention with this reporting period was to obtain a full five years of monitoring data for each site (*n*=20, based on four samples per year). Unfortunately the mid 2005 sampling round extended beyond the 1 August 2005 starting date used in the extraction of the monitoring results from Greater Wellington's Hilltop database, with five sites not being sampled until early August. As a result, these five sites have one extra set of monitoring results (ie, *n*=21). Also, there were 25 sites where *n*<20 (as low as *n*=16), arising from the site not being able to be accessed on one or more sampling occasions.

Prior to data analysis, median absolute deviation (MAD) was calculated on a per site and per variable basis to identify potential outlier values, (Helsel & Hirsh 1992). Typically, outliers are defined as those results that are at least two times the MAD away from the median, although a threshold of four times the MAD away from the median is appropriate for identifying the effects of sampling, analytical and/or data entry errors in a hydrochemical dataset (Daughney 2007). However, in the GQSoE dataset, there was no strong evidence that data points four times the MAD away from the median were genuine 'outliers' (eg, these points were often just higher than other data points or simply represented non-censored values). Therefore, results identified as potential outliers were not excluded from subsequent statistical analyses.

Treatment of censored data (ie, values reported below the analytical detection limit) for state and temporal trend analyses is outlined in Section 4.2.1 and 5.1 respectively. The principal graphical plots employed in this report are box-and-whisker plots. Interpretation of these plots is outlined in Section 4.2.1.

3. Overview of groundwater in the Wellington region

This section provides a brief overview of groundwater in the Wellington region, including hydrogeological features, groundwater management zones and the key factors that can influence groundwater quality. These factors include both natural processes and anthropogenic pressures such as agriculture and horticulture. Significant consented activities with the potential to impact on groundwater quality are also summarised.

3.1 Hydrogeology

There are three principal groundwater areas in the Wellington region: the Kapiti Coast, Lower Hutt Valley and the Wairarapa Valley. Secondary groundwater areas include Upper Hutt, Mangaroa valley, Wainuiomata valley and sections of the eastern Wairarapa coastline. Aquifers in all of these areas are found in unconsolidated alluvial, aeolian (wind-blown) and beach sediments of varying grain size. Minor aquifers are also found in limestone and fractured greywacke in some areas of the region.

Detailed descriptions of the geological setting of each of the major groundwater areas can be found in Jones and Baker (2005), with revised information for the Wairarapa Valley reported by Gyopari and McAlister (2010a, 2010b & 2010c); only a brief overview of the recharge mechanisms and productivity is given here, taken from Keenan et al. (2012).

3.1.1 Kapiti Coast

The Kapiti Coast groundwater area has three broad types of aquifers associated with different types of deposits: recent river gravels, glacial and interglacial deposits, and post-glacial beach and dune sand deposits. The aquifers present in the recent river gravels of the Otaki River, Waikanae River and Waitohu Stream are recharged by surface waterways and are high-yielding. The confined aquifer system associated with glacial and interglacial deposits is predominantly rainfall-recharged and moderate-yielding. At the coast, aquifers associated with the dune sands are low-yielding and rainfall is the dominant recharge mechanism.

3.1.2 Lower Hutt Valley

The aquifers of the lower Hutt Valley were formed by the thick accumulations of gravel deposited by the Hutt River. The primary aquifer of the valley is found in the Waiwhetu gravels, and is separated into an upper and lower aquifer, recharged by the Hutt River. The upper Waiwhetu aquifer is highly productive with transmissivity values as high as 35,000 m^2/day (Jones & Baker 2005).

3.1.3 Wairarapa Valley

The complex system of aquifers in the Wairarapa may be classified into three broad categories: alluvial fan deposits, reworked river gravels and stratified lower valley deposits (Jones & Baker 2005). The alluvial fan deposits are poorly sorted gravel and sand that form low transmissivity aquifers predominantly recharged by rainfall. In the upper Wairarapa Valley these gravels are traversed by active faults, and springs are common at the base of the fault scarps. These springs supply a number of small streams in the valley.

Re-worked river gravels are found alongside the large waterways of the Wairarapa Valley and form highly productive unconfined aquifers. These aquifers are in direct connection with surface water and loss from the rivers is the dominant recharge mechanism.

The stratified lower Wairarapa Valley deposits comprise sand and gravel layers separated by fine grained marine sediments. These thin sand and gravel layers form a series of productive confined aquifers. The recharge mechanism for these aquifers is thought to be a combination of rainfall and river losses from the Tauherenikau fan to the north and from the sides of the valley, and from losses from the Ruamahanga River. Discharge from the lower valley aquifers is limited as the degree of connection with the sea is thought to be constrained geologically (Hughes & Gyopari 2011).

3.2 Groundwater management zones

Groundwater management zones have been defined in all principal and some secondary groundwater areas in Greater Wellington's Regional Freshwater Plan (WRC 1999a, Figure 3.1). These zones are used as a framework to help manage the region's groundwater resources. Although there are currently 44 groundwater management zones within the region, a recent re-evaluation of hydrogeology and geology in the Wairarapa Valley (Gyopari & McAlister 2010a, 2010b & 2010c) has revised the zone boundaries in this area, with a proposal to reduce their total number from 29 to 17 (Hughes & Gyopari 2011) (Figure 3.2).

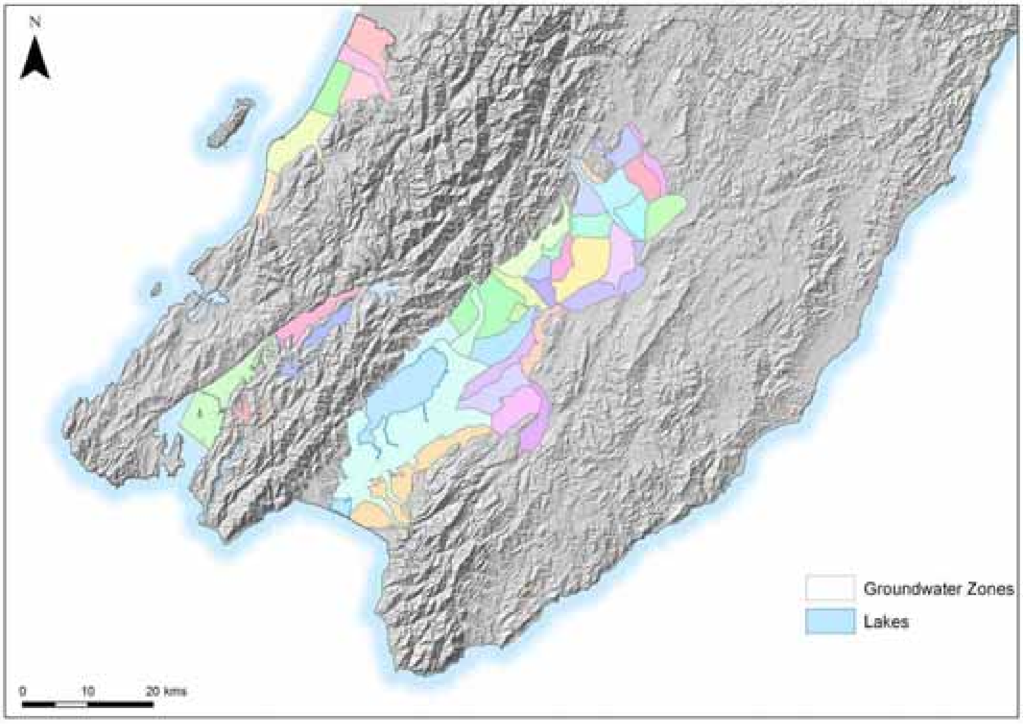

Figure 3.1: Groundwater management zones in the Wellington region as set out in the existing Regional Freshwater Plan (WRC 1999a)

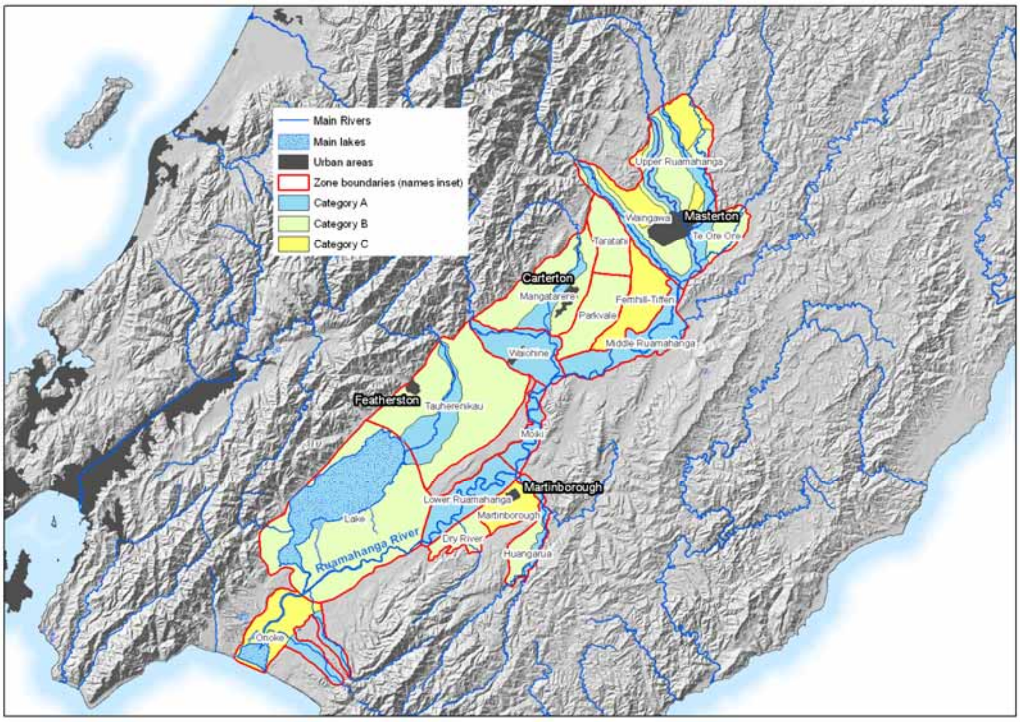

Figure 3.2: Proposed new groundwater management zones for the Wairarapa Valley (Hughes & Gyopari 2011)

The revised zone boundaries divide groundwater into three categories of A, B and C which represent the ranging degree of hydraulic connectivity with surface water (direct, moderate and very little, respectively). It is proposed that categories A and B will be managed under surface water allocation policy and category C under groundwater allocation policy (Keenan et al. 2012).

3.3 Influences on groundwater quality in the Wellington region

Water is an extremely effective solvent. Salts and minerals are easily dissolved into, and transported by, water. Therefore, the chemical composition of groundwater can naturally be highly variable depending on its origin, surrounding aquifer geology and residence time of water within the aquifer. Other influences on the chemical composition of groundwater include anthropogenic activities such as land use practices and industrial discharges.

Groundwater can be assigned to hydrochemical facies or water types based on the unique hydrochemical composition of the groundwater in individual bores. Assignment of groundwater to a particular water type can indicate environmental factors (such as origin of recharge, landuse, lithology and confinement) which may influence the hydrochemical composition of groundwater in each bore. Classifying groundwater into individual water types can aid analysis by establishing baselines for natural groundwater hydrochemistry as opposed to groundwater quality affected by human activity (Daughney & Reeves 2005). An assessment of water types in the Wellington region is presented in Section 4.

3.3.1 Natural processes

As groundwater flows from its point of recharge to point of discharge, its chemical composition is naturally influenced by a number of factors, including:

- Source of recharge
- Geological and pedological characteristics of the aquifer and soil
- Residence time in the aquifer
- Confinement and depth of the aquifer system
- Hydraulic characteristics of the aquifer system

Groundwater in the unconfined rainwater-recharged aquifers generally has greater concentrations of dissolved solids. Soil acids and evapotranspiration increase the concentration of dissolved solids in the soil zone. As the rainwater infiltrates into the soil zone, it transports the dissolved solids into the groundwater. In contrast, unconfined groundwater recharged directly by river losses generally has lower concentrations of dissolved solids because water has had less interaction with surrounding geology and pedology, and there is less evapotranspiration before moving into the aquifer system (Hem 1985; Freeze & Cherry 1979). Groundwater in confined aquifer systems generally has greater concentrations of dissolved solids due to greater interaction with surrounding geology and pedology.

Rock-water interaction influences the chemical composition of the groundwater through dissolution of salts and minerals from surrounding rock to groundwater. Concentrations of total dissolved solids and most of the major ions (calcium, magnesium, sodium, potassium, bicarbonate, sulphate and chloride) generally increase with increased contact time between the aquifer matrix and groundwater. Numerous investigations worldwide show that shallow groundwater in recharge areas has lower concentrations of dissolved solids than the groundwater deeper in the same system, and is lower in dissolved solids than the water in shallow zones in the discharge areas (Freeze & Cherry 1979).

There is also a natural tendency for groundwater to chemically evolve towards the composition of seawater with increases in aquifer confinement and depth and decreases in groundwater flow (transmissivity) (Chebotarev 1955). However, such saline brines are not typically found in New Zealand groundwater systems (Daughney & Randall 2009).

The amount of available dissolved oxygen in groundwater can influence the form of elements or chemical species which accumulate in groundwater. In general, recently recharged, shallow groundwater is oxygen-rich, while older and/or confined groundwater is oxygen-poor. For example, nitrogen in an oxygen-rich groundwater generally would be in the form nitrate-nitrogen. However, groundwater depleted of oxygen would contain the reduced form of nitrogen, ammoniacal nitrogen. Elements and chemical species such as manganese, iron, sulphide, methane and arsenic tend to accumulate in groundwater under oxygen-poor conditions under natural conditions but can also be introduced to groundwater systems through human activity (Daughney & Wall 2007).

3.3.2 Anthropogenic effects

A major influence on the chemical composition of groundwater is from the activities of humans. Land use practices can directly influence groundwater quality especially in shallow and unconfined aquifers where there is a greater hydraulic connectivity between the surface and unconfined aquifers.

However, contamination is not limited to the shallow groundwater zone. Semi-confined and confined aquifer systems can also be at risk, if recharge occurs in an area of intensive land use, even if that recharge area is many metres or kilometres away. The rate at which groundwater flows through an aquifer is just as important to note; it is possible that contamination of groundwater may have occurred historically but still has a significant impact on present groundwater quality. For example, a study of elevated nitrate nitrogen concentrations in the Te Ore Ore plains aquifers north of Masterton (Van der Raaij 2000) suggested contamination in the area was from fertiliser applied 20 years or more prior to the study.

(a) Land cover and use

General land use can be inferred from land cover information. The most up-to-date land cover information for the Wellington region is based on aerial photographs taken in 2008 by the Ministry for the Environment (MfE 2010) (Figure 3.3). According to this source of information, close to half of the 812,000 ha area of the Wellington region is in pasture, with 21.6% high producing pasture and 28.0% low producing pasture[4]. The majority of high producing pasture is located within the Wairarapa Valley and near Otaki, while the low producing pasture is predominantly located in the eastern hill country of the Wairarapa, and also the hill country of Wellington and Porirua.

Over 290,000 ha (37.0%) of the region's land area remains under indigenous forest cover, with a large proportion of this found in the Tararua Forest Park. Exotic forest is found throughout the hill country on the western and eastern sides of the region, but makes up a smaller proportion of the land area (8.6%). There is just over 4,000 ha (0.5%) of horticulture (including cropping) in the region, located mainly around Otaki and localised areas of the Wairarapa Valley. Urban areas occupy 2.4% of the region, and are concentrated mainly in the western side of the region around Wellington city, Porirua and the Hutt Valley.

Sorensen (2012) summarises recent land use change across the region, based on aerial photographs taken in 2002[5] and 2010, interpreted from soil intactness surveys reported by Crippen and Hicks (2004) and Crippen and Hicks (2011). According to these surveys, the largest land use change between 2002 and 2010 was a reduction in drystock farming (2.6% or over 21,000 ha of the region's land area), with over half of this reduction attributed to the conversion of pasture land to exotic forest. The majority of land converted into exotic forest over this time is located in the eastern hill country of the Wairarapa which

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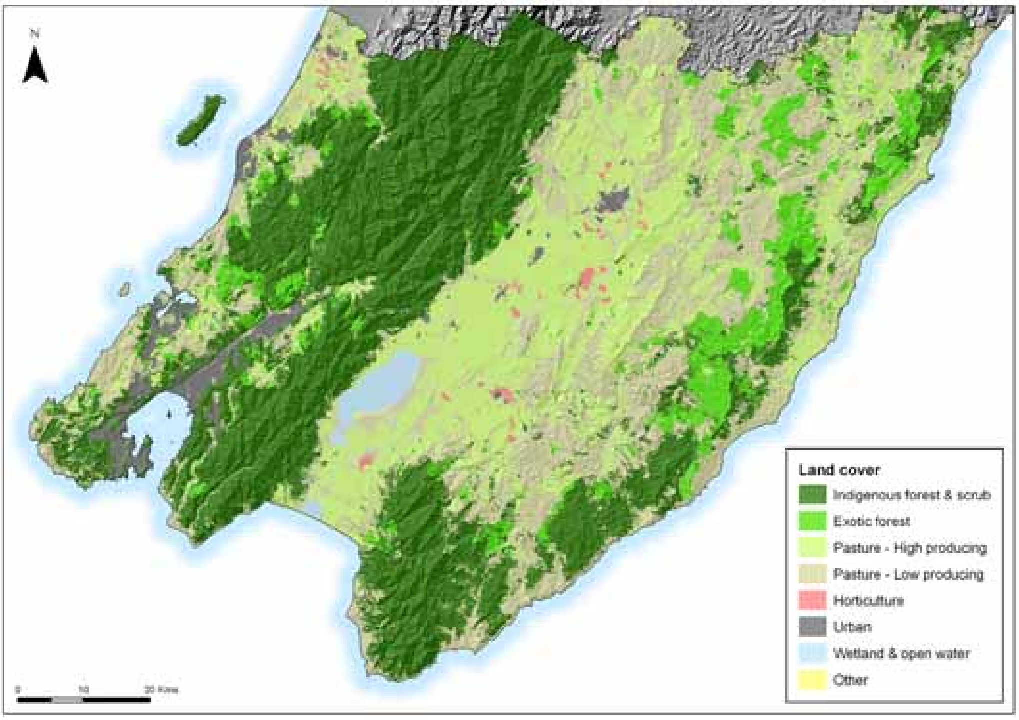
[4] High producing pasture is defined as 'sown pasture'– pasture with a medium to high dry matter production, including rye grass and clover. In contrast, low producing pasture is defined as 'adventive grassland' and includes native grasses and browntop and other pasture species with low dry matter production (Ministry of Works and Development 1979).

[5] The aerial photographs which were interpreted were taken from 2001 to 2003 across the region. For the purposes of this report the period is reported as 2002.



(Source: LUCAS – MfE 2010)

Figure 3.3: Land cover of the Wellington region, derived from aerial photographs taken in 2008

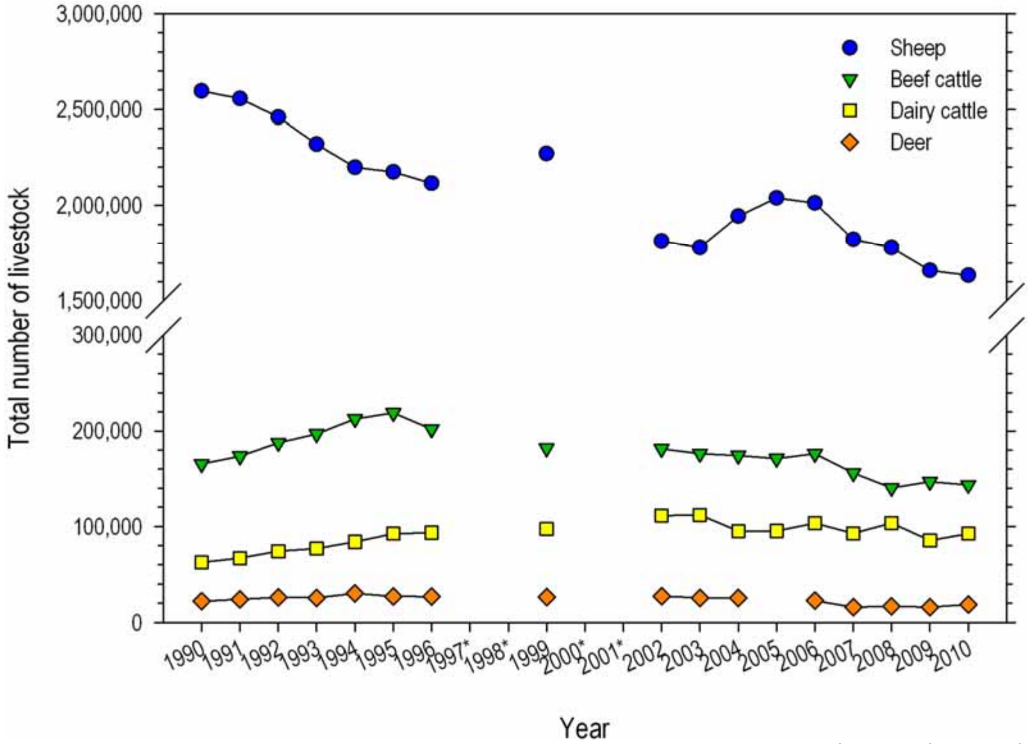
is highly susceptible to erosion (Sorensen 2012). Between 2002 and 2010 small increases were also evident for dairying (0.7% of region's land area and approximately 5,600 ha[6]) and the 'other' category (0.7%), which includes urban areas. Changes in the area of the region under indigenous forest, and cropping and horticulture were negligible (Sorensen 2012).

(b) Livestock numbers

With approximately half of the region covered in pasture, agriculture is an important industry for the region. Figure 3.4 shows that while there are still significantly more sheep than all other livestock in the region, sheep numbers have reduced consistently since 1990. In contrast, beef cattle and deer numbers remained reasonably consistent (although numbers for both have decreased since 2006) and dairy cattle increased significantly from 62,521 in 1990 to 92,375 in 2010.

In addition to an increase in dairy cows in the region, based on Dairy NZ (2010) data presented in Sorensen (2012), there has been a reduction in effective farming area; collectively this has resulted in a 33% increase in average herd size for the region – from 299 in 2002 to 399 in 2009 (Table 3.1). This also translates to an increase in the average stocking rate from, on average, 2.54 cows per hectare of dairy farm land in 2002/03 to 2.80 cows per hectare in 2009/10. While the decrease in effective farming area bucks the national trend, the increases in both average herd size and stocking rates in the Wellington region are very similar to the overall trends at the national level (Table 3.1).

[6] Sorensen (2012) notes that this is in contrast to data reported by Dairy NZ (2010), which indicates an 11% decrease in effective farming area for dairying (See Table 3.1).



(Source: Dairy NZ 2010)

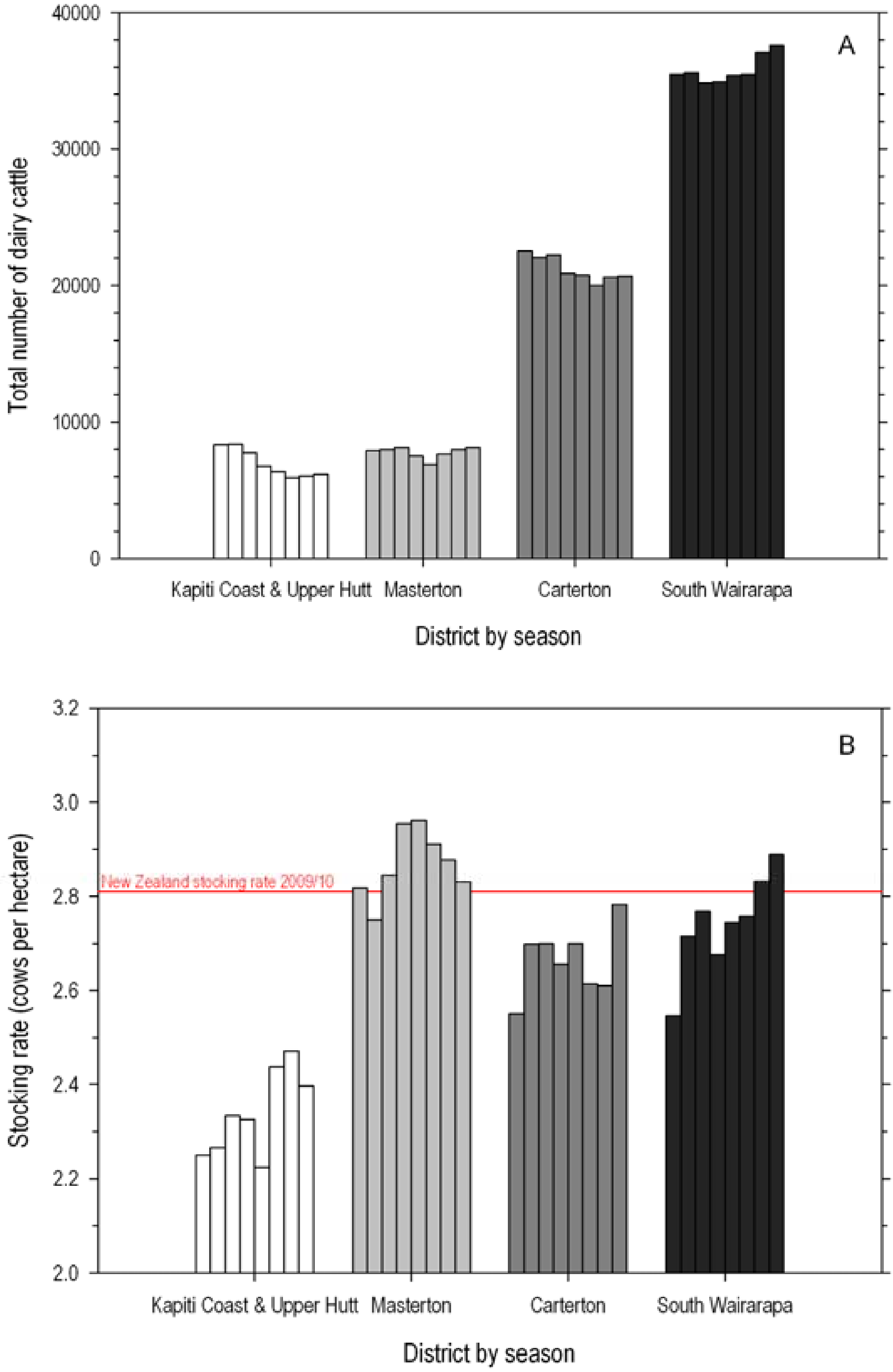
Figure 3.4: Numbers of livestock within the Wellington region, 1990–2010

* Data not available

Table 3.1: Dairy farming area, herd size and stocking rates for both the Wellington region and all of New Zealand (Source: DairyNZ 2010)

Season	Effective farming area (ha)		Average herd size		Average stocking rate (cows per hectare)	
	Wellington	New Zealand	Wellington	New Zealand	Wellington	New Zealand
2002/03	29,235	1,463,281	299	285	2.54	2.57
2003/04	27,855	1,421,147	311	302	2.66	2.72
2004/05	26,964	1,411,594	332	315	2.71	2.74
2005/06	26,307	1,398,966	347	322	2.66	2.73
2006/07	25,778	1,412,925	352	337	2.69	2.79
2007/08	25,629	1,436,549	371	351	2.70	2.79
2008/09	26,181	1,519,117	390	366	2.74	2.79
2009/10	25,898	1,563,495	399	376	2.80	2.81
% change 2002–2010	-11	7	33	32	10	9

Looking at the region's dairy farming on a district basis, South Wairarapa contains nearly half of all the dairy cattle in the Wellington region. It is also the district with the most growth in dairy cattle numbers, increasing from 35,466 in 2002/03 to 37,577 in 2009/10 (Figure 3.5). The second largest dairying district in the region is Carterton, with the combined dairy cattle numbers from the districts of Kapiti Coast and Upper Hutt, along with dairy cattle numbers in Masterton, making up smaller proportions of the total dairy cattle numbers for the region.



(Source: Dairy NZ 2010)

Figure 3.5: Total number of dairy cattle (A) and dairy cattle stocking rates (cows per hectare) (B) for each district with dairy cattle in the Wellington region, 2002/03 to 2009/10. Each bar represents a milking season, with the left-most bar for each district representing 2002/03 and the right-most bar representing 2009/10.

Although South Wairarapa and Carterton contain the majority of dairy cattle in the region, Masterton has until recently contained the highest stocking rate, peaking at 2.96 cows per hectare in 2006/07 (Figure 3.5); although this decreased to 2.83 in 2009/10, it is still above the national average stocking rate (Table 3.1). Stocking rates in both South Wairarapa and Carterton have steadily increased since 2002/03, peaking at 2.89 and 2.78 cows/ha, respectively, in 2009/10.

(c) Horticulture

A small proportion of the region is used for various horticultural uses. Information from MfE (2010) suggests that in 2008 approximately 0.5% of the region's land was used for horticulture, while Crippen and Hicks (2011) determined that in 2010 1.4% of the region's land was used for cropping and horticulture. Although minor in terms of the proportion of the region's land resource, horticulture is an important land use for the region, especially in areas around Otaki, Te Horo, Greytown and Martinborough.

Although Statistics New Zealand data suggest that horticulture (excluding vineyards) has declined by over 40% in the region from 2002 to 2007 (Table 3.2), accurate information on horticultural land use is difficult to obtain and more detailed analysis of information would be required before it could be established if horticulture (particularly orchards and vegetable growing) has in fact decreased over this period[7]. More information is available for vineyards from the New Zealand Winegrowers Vineyard Surveys, which shows that the area of vineyards has grown by 44% from 2003 to 2009 (Table 3.2). However, the rate at which vineyards have increased has slowed in the past few years, and the region remains only a minor producer of wine in New Zealand.

Table 3.2: Area (hectares) of land used for horticulture within the Wellington region by crop type

(Source: Statistics New Zealand & New Zealand Winegrowers Vineyard Surveys)

	2002	2003	2007	2009	% change
Orchard crops	850	–	545	–	-36
Vegetable crops	448	–	82	–	-82
Other (including flowers)	117	–	193	–	65
Vineyards	–	595	–	859	44
Total*	2,010		1,679	-16	

* Total area of horticulture, which includes orchard crops, vegetable crop, other and vineyards.

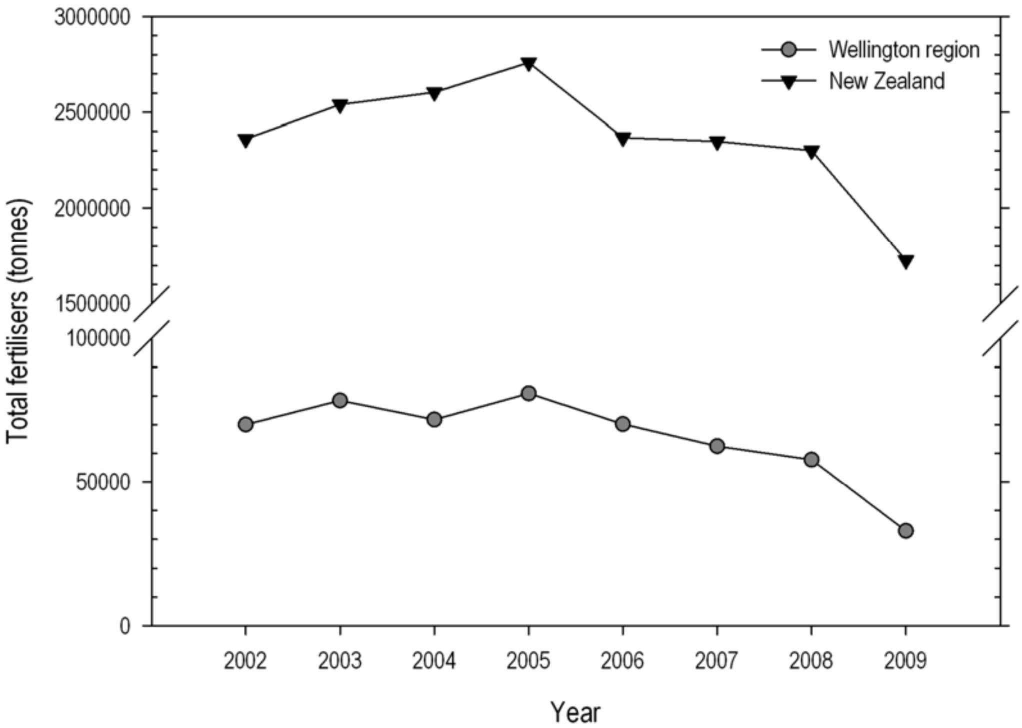
(d) Fertiliser usage

Most New Zealand soils, including soils in the Wellington region, are not naturally productive. They tend to be thin and slightly acidic, with low levels of nutrients such as nitrogen, phosphorus and sulphur. To increase the productivity of soils, fertilisers and lime are applied to the land. With increased intensification in land use and higher demands for production in more recent

7 Data in Crippens and Hicks (2011) suggest horticulture actually increased by 0.4% between 2002 and 2010 – see Sorensen (2012).

times, farmers have used nitrogen to supplement nitrogen-producing legumes, such as clover (Fert Research 2009).

Information on the volumes of different fertiliser types used throughout the region is difficult to obtain. However, by comparing the trends of total fertiliser usage for the region with that across all of New Zealand, assumptions can be made about how much fertiliser is being applied to the land and in what kind of volumes. Figure 3.6 shows a steady decrease in the total amount of fertilisers applied to land in the Wellington region since 2005, closely mirroring the national trend. In 2009, New Zealand's phosphate consumption was at an 18-year low, nitrogen usage declined to a 7-year low and the use of potassium fertilisers was at its lowest level in 17 years (Fert Research 2009). Because the Wellington region has closely followed the national trend in total fertiliser usage since 2002, it is likely that the region has similar patterns to those being exhibited nationally with regard to the use of specific fertilisers.



(Source: Statistics New Zealand)

Figure 3.6: Total fertiliser usage between 2002 and 2009 for the Wellington region and across all of New Zealand

In addition to artificial fertilisers, it has become common practice to apply animal effluent to land as effluent is a good source of nutrients. Anecdotal evidence suggests that the number of hectares of land on which dairyshed effluent is applied has increased over the last 10 years, probably partly in response to dairy intensification as well as concerted efforts to eliminate discharges of dairyshed effluent to water[8]. There are also several resource consents exercised in the region allowing other types of effluent, such as pig and poultry effluent, to be applied to land. Agricultural effluent discharges to land are discussed further in the next section.

[8] According to Milne and Perrie (2005), there were 63 consented discharges of dairyshed effluent to water in the Wellington region in 1995 – this had dropped to just three by December 2004.

3.3.3 Significant consented activities

This section briefly outlines some of the specific consented land use activities with the potential to impact on groundwater quality. These include discharges of agricultural, municipal and industrial wastewater to land, discharge from landfills and water abstraction. The resource consent information presented in this section was drawn from Greater Wellington's 'Ozone' database and was current as at 30 June 2010.

(a) Agricultural wastewater discharges

There are approximately 200 operative permits for discharges of agricultural wastewater to land across the region (Figure 3.7). The majority (over 95%) of these permits are for dairyshed effluent discharges, mainly in the Wairarapa. Other agricultural discharges to land include piggery effluent (in the Mangatarere Stream catchment near Carterton, in south Featherston and near Greytown) and poultry effluent (discharged to land in the Coastal and Waitohu groundwater management zones near Otaki).

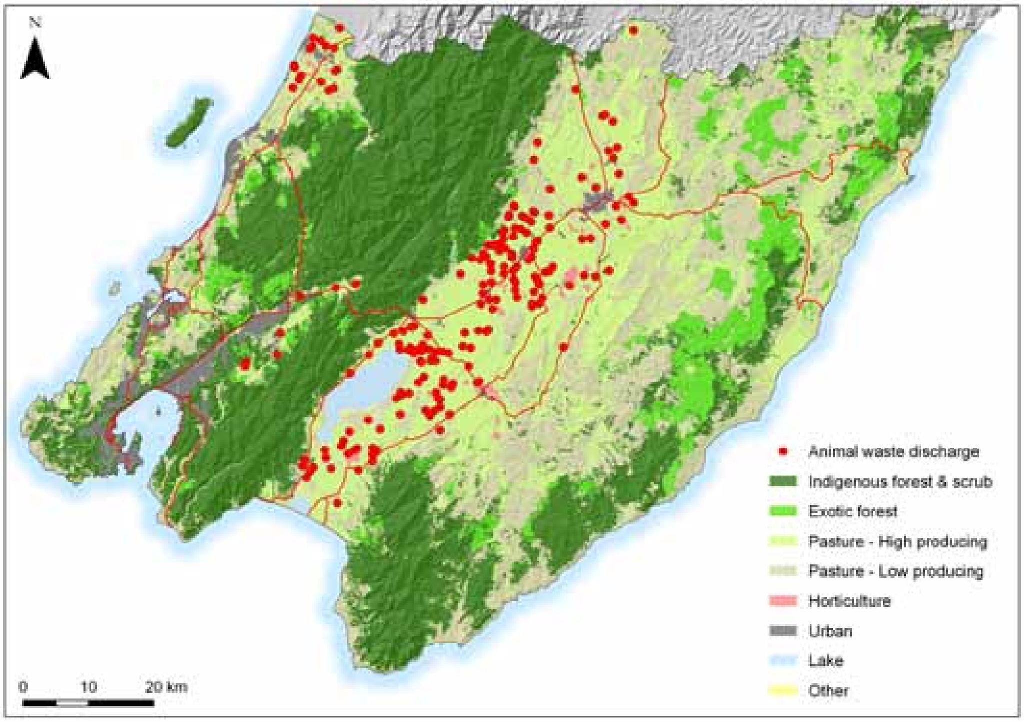


Figure 3.7: Consented agricultural wastewater discharges to land in the Wellington region as at June 2010

(b) Domestic and municipal wastewater discharges

There are approximately 90 discharge permits for sewage-related discharges to land in the Wellington region. Most of these discharges relate to community treatment facilities in small settlements (eg, Tinui, Castlepoint and Lake Ferry) and recently developed rural subdivisions (eg, Flat Point and Norfork Road near Masterton), as well as individual properties located in areas with no reticulated sewerage (eg, Te Horo Beach, Paekakariki, Pauatahanui, the Mangaroa

Valley and Riversdale[9]) that do not meet Greater Wellington's permitted activity rules for on-site wastewater discharges[10].

Of the larger towns and cities, only Otaki currently discharges treated wastewater to land on a permanent basis. Carterton also discharges treated wastewater to land but this is currently limited to three months of the year when conditions allow. Under a new consent granted to Masterton District Council in 2009, from 2013 onwards, wastewater from Masterton will progressively be discharged to land (see Greenfield et al. 2012 for further details).

(c) Industrial wastewater discharges

There are just over 40 operative permits to discharge industrial wastewater to land, although some of these relate to short-term earthworks activities. The main types of industrial discharges include winery wastewater, timber treatment, fertiliser/compost production, paua wastewater and slaughterhouse wastewater. There are also several resource consents that authorise the discharge of water treatment plant waste products to land, typically suspended sediment and aluminium associated with filter treatment backwash water.

(d) Landfill discharges

Of the 16 municipal landfills in the Wellington region consented to discharge leachate to land[11] (Figure 3.8), only the Southern Landfill (Wellington city), Spicers Landfill (Porirua), Hutt Valley Landfills (Silverstream and Wainuiomata) and the Otaihanga Landfill (Kapiti) remained operational as at 30 June 2010. There are also six private landfills (mostly cleanfills) operating in Wellington city (3), Porirua (1) and Wainuiomata (1) with consents to discharge contaminants to land (although only Seaside Haven Limited and T & T Landfills Limited hold consents to discharge landfill leachate to land).

(e) Water abstraction

Large scale abstraction of groundwater for irrigation can change the water chemistry within an aquifer system, inducing un-natural recharge to the aquifer system from sources that are chemically and bacteriologically different from the existing groundwater aquifer. Large scale abstraction of surface water that is hydraulically connected to groundwater also has the potential to impact on groundwater chemistry, particularly in shallow aquifers.

According to Keenan et al. (2012), as at the end of 2010, consented water abstraction in the Wellington region equated to approximately 414 million m^3/year; this represents a 54% increase on the 269 million m^3/year of water allocated in 1990. Groundwater makes up around one-third of the allocated water resource, with around 60% of this used for irrigation and 36% used for public or community water supply.

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9 Note that as of October 2011, Riversdale is now serviced by a community wastewater treatment plant. Masterton District Council holds a resource consent to discharge wastewater from the plant to land west of the beach settlement.

10 Under Rule 7 of Greater Wellington's Regional Discharges to Land Plan (WRC 1999b), a resource consent is only required for domestic wastewater discharges to land if the volume of discharge exceeds 1,300 L/day and the discharge occurs within close proximity of a surface water course (within 50 m if managed for water supply and within 20 m in all other cases).

11 Several types of resource consents are associated with landfill discharges to land, notably solid waste and stormwater. Only leachate discharges are outlined here since they have the greatest potential to contaminate groundwater.

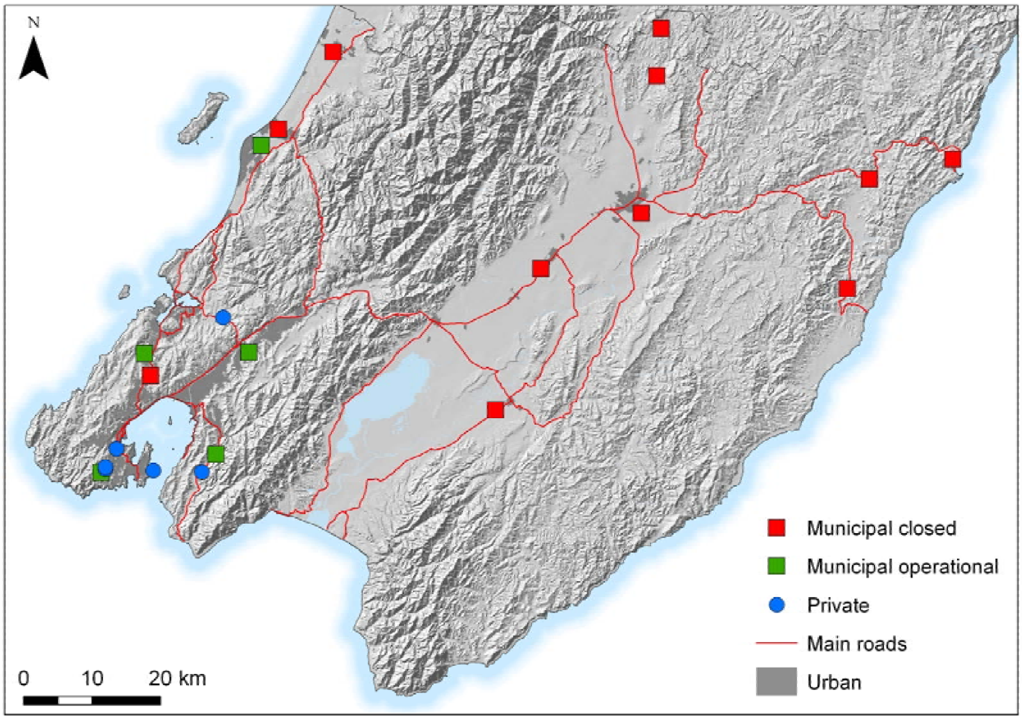

Figure 3.8: Consented discharges of landfill leachate to land in the Wellington region as at June 2010

Most (75%) of the region's increase in allocated groundwater has been for irrigation in the Wairarapa, mainly for dairy pasture (70%), non-dairy pasture (17%) and vineyards (8%). A further 14% of the increase was for public water supply in the Kapiti sub-region. Other significant increases in groundwater allocation have occurred for water supply in the Wairarapa (5% of the overall increase in groundwater allocation) and irrigation on the Kapiti Coast (3% of the overall increase in groundwater allocation). Keenan et al. (2012) note that the groundwater areas with the largest increase in allocation over 1990–2010 are generally associated with larger rivers such as the Ruamahanga, Waiohine, Tauherenikau and Waikanae rivers.

4. Groundwater quality – state

This section presents an analysis of the current state of groundwater quality in the Wellington region, utilising routine GQSoE monitoring data gathered quarterly over the five-year period ending in July 2010. An overview of spatial variation in hydrochemistry for the region is presented first, followed by an assessment of compliance with standards and guidelines focussing on nine key groundwater quality variables. A water quality index is then used to summarise the suitability of the region's groundwater for potable use, along with a second index that attempts to summarise the potential for aquatic toxicity-related impacts of groundwater discharge to surface water ecosystems.

4.1 Spatial variation in groundwater chemistry across the region

4.1.1 Approach to analysis

Multivariate data analysis was undertaken to look at spatial variations in groundwater chemistry across the Wellington region. Two multivariate approaches were employed using Statgraphic Centurion (Version 15): Principal Components Analysis (PCA) and Hierarchical cluster analysis (HCA). Cross-tabulation was then used to investigate potential relationships between the resulting hydrochemical clusters and aquifer confinement, bore location, lithology and overlying land use. Details on the multivariate analysis and cross-tabulation techniques are provided in Appendix 3.

PCA and HCA were conducted using median values (log-transformed to the base ten) for 15 water quality variables routinely tested at quarterly intervals as part of the GQSoE monitoring programme between 1 August 2005 and 31 July 2010: bromide, calcium, chloride, fluoride, iron, bicarbonate, potassium, magnesium, manganese, sodium, ammonia, nitrate, dissolved reactive phosphorus (DRP), silica and sulphate. These variables were selected on the basis that they are most likely to determine the extent of rock-water interaction and human influence on groundwater quality. These variables were also used to classify groundwater chemistry in the last groundwater SoE report for the Wellington region (Jones & Baker 2005).

The median value for each variable was scaled in accordance with its z-score to ensure all variables had equal influence in the HCA and PCA (Daughney 2007).

4.1.2 Principal component analysis (PCA)

PCA identified two significant components (Eigenvalue >1) which collectively explained 73% of the variance in the groundwater quality data (Figure 4.1). Groundwater component one explained 58% of the variance in the data and had positive weightings for all variables except nitrate and sulphate. Groundwater component 2 explained 14% of the variance in the data and showed nitrate and sulphate were positively correlated to all major cations and anions but inversely correlated to ammonia, iron, manganese and DRP.

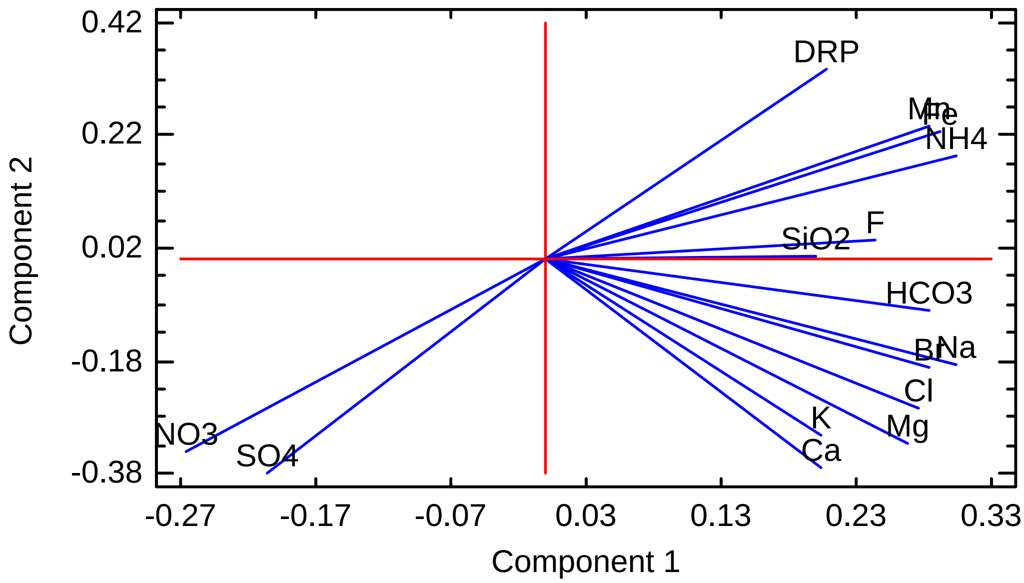

Figure 4.1: Bi-component plot based on Principal Component Analysis using scaled median results (log-transformed to the base ten) of 15 selected variables measured quarterly at 71 sites in the GQSoE monitoring programme between August 2005 and July 2010

The strong negative loading of nitrate and a strong positive loading of ammonia, iron and manganese in component one suggests that hydrochemistry is driven mainly by the oxygen-rich and oxygen-poor environments (redox potential). Nitrate is the dominant form of nitrogen in oxygen-rich groundwater and ammonia is the dominant form of nitrogen in oxygen-poor groundwater. Likewise, sulphate is the dominant form of sulphur in oxygen-rich groundwater; in oxygen-poor groundwater with low redox potential, sulphur is present as hydrogen sulphide (H_2S). Similarly, dissolved iron and manganese are generally only present in oxygen-poor groundwater (Daughney & Randall 2009).

Component one also displays positive weighting for all variables except nitrate and sulphate. This suggests a distinction between young or fresh groundwater with low TDS concentrations and evolved groundwater with greater TDS concentrations (groundwater subjected to intensive rock-water interaction). Given that nitrate and sulphate are inversely correlated to TDS it is likely that sulphate and nitrate are added to groundwater by human activity.

Component two exhibits strong negative weighting of bromide, calcium, chloride, potassium, magnesium and sodium; this indicates that these substances tend to occur together. Similarly, strong positive correlations of manganese, iron and ammonia indicate that these substances likely occur together. These weightings further support redox potential as being a main controller of groundwater chemistry. DRP is not a redox-sensitive substance, yet its weightings indicate that it tends to co-occur with dissolved iron, manganese and ammonia but not with nitrate or sulphate. This suggests that DRP is derived from natural water-rock interaction rather than from human activities. Silica, bicarbonate and fluoride have weightings close to zero and do not appear to be strongly correlated with other variables.

Independent studies, using PCA of groundwater chemistry data across New Zealand, have identified a third component that shows a distinction between calcium bicarbonate and sodium chloride water types (Daughney & Reeves 2005). Although a third component was not identified in this PCA assessment, further analysis of median values using HCA and graphic representation of the data by way of a Piper diagram (presented in the next section) indicates that the groundwater at the majority of GQSoE bores is dominated by both sodium and calcium.

Overall, PCA conducted with the median values from the GQSoE data set suggests that natural influences (rock-water interaction and redox potential) influences (rock-water interaction and redox potential) and human activity are opposing factors that control groundwater chemistry in the Wellington region.

4.1.3 Hierarchical cluster analysis (HCA)

Prior to conducting HCA, the Nearest Neighbour Algorithm was used to group GQSoE bores based on the similarity of groundwater chemistry recorded at each bore; this enabled bores with unique groundwater chemistry relative to other GQSoE bores to be identified. Bores with very unique hydrochemistry are termed 'residuals' and should generally be excluded from further HCA analysis. Using the Nearest Neighbour Algorithm, bores R25/5164, S27/0268 and S27/0522 were identified as possible residuals due to lower silica (R25/5164), higher sodium and calcium (S27/0268), and higher calcium and magnesium (S27/0522) concentrations relative to other GQSoE sites. However, on closer examination, the hydrochemistry at these sites was not considered too dissimilar to the hydrochemistry at other GQSoE bores and so they were not excluded from subsequent analysis[12].

Following this initial assessment, HCA was conducted using Ward's method to classify the 71 GQSOE bores into clusters based on the similarity and dissimilarity of their respective hydrochemistry (based on median values). Figure 4.2 displays the thresholds at which hydrochemically distinct clusters were identified. Box plots (based on median values) were used to evaluate the hydrochemical differences between each of the sub-clusters (refer to Appendix 3 for these box plots).

Two main clusters (or groups) were identified by HCA at the first (highest) threshold: Cluster A and Cluster B[13] (individual cluster assignments of the GQSoE bores are listed in Appendix 3). In general, Cluster A is typical of river drainage from un-weathered greywacke (Tararua Range) and rainfall recharge, with a chemical signature of low TDS, and is oxygen-rich with low concentrations of variables such as ammonia, iron and manganese. In contrast, Cluster B is typical of river drainage from weathered greywacke or groundwater influenced by oxygen-poor conditions.

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12 Bores S27/0268 and S27/0522 were also identified as residuals in the last groundwater quality SoE report for the Wellington region (Jones & Baker 2005) but were not excluded from further analysis in that report.

13 The naming convention for the main clusters A and B and the nine sub-clusters is arbitrary.

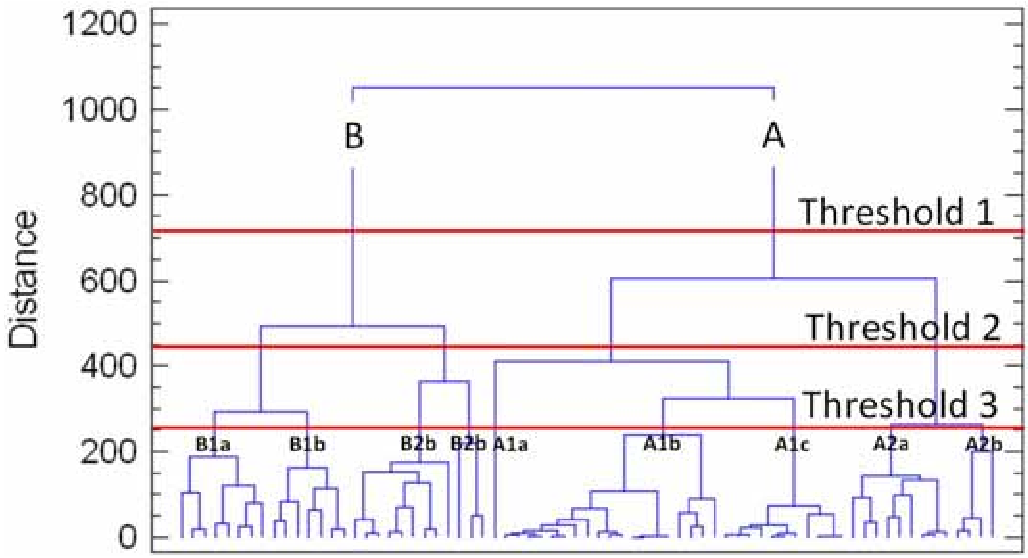


Figure 4.2: Dendrogram displaying the level of dissimilarity in hydrochemistry at all GQSoE bores. This dendrogram is based on the Ward's method, using median results (log transformed to the base ten) from 15 selected variables measured quarterly in the GQSoE monitoring programme between August 2005 and July 2010. The red line denotes the threshold levels at which water chemistry is most dissimilar to other clusters of water quality.

HCA at the third (lowest) threshold identified nine sub-clusters. Hydrochemical variations between the nine sub-clusters are depicted on the piper diagram in Figure 4.3 and summarised in Table 4.1. Most sub-clusters are dominated by sodium and calcium cations and bicarbonate and chloride anions, but at different cation to anion ratios. This is consistent with the dominant hydrochemcial constituents found in groundwater worldwide (Freeze & Cherry 1979). The median values of seven additional variables (conductivity, pH, TDS, dissolved oxygen, zinc, boron and total organic carbon) were used to further interpret the hydrochemistry of the nine sub-clusters (refer Appendix 3).

The spatial spread of sub-cluster groups in the Wellington region (Figure 4.4) suggests that groundwater chemistry is influenced by recharge mechanism and aquifer confinement. The cluster pattern also suggests that groundwater chemistry changes with the migration of groundwater from oxidised to reduced environments, which coincides with increased aquifer confinement.

On the Kapiti Coast, the majority of bores are assigned to sub-clusters within Cluster A (Figure 4.4). These bores are located in unconfined to semi-confined aquifers where there is a large amount of rainfall recharge (foothills of the Tararua Range) and/or river recharge (Waikanae and Otaki rivers). Therefore, large rates of rainfall and river recharge result in lower concentrations of major ions in the underlying groundwater (Tidswell 2009). The presence of nitrate and sulphate are indicative of human impacts on groundwater quality. Bores on the Kapiti Coast that are assigned to sub-clusters within Cluster B are generally located in the deep confined aquifers in the Te Horo area. Bore R25/5165 was also assigned to Cluster B despite being located in the unconfined area; this is likely to be because the groundwater in this bore has high median sodium and chloride concentrations (similar to those concentrations found in the B group sub-clusters), reflecting the bore's close proximity to the sea at Te Horo Beach on the Kapiti Coast. As discussed later in this section, water chemistry in this bore may also be affected by discharges from on-site wastewater systems in the area.

Sub-cluster	Water type
A1a	Na-Cl
A1b	Na-Ca-Mg-HCO_3-Cl
A1c	Ca-Na-HCO_3-Cl
A2a	Na-Ca-Mg-HCO_3-Cl
A2b	Ca-Na-HCO_3-Cl
B1a	Na-Ca-HCO_3-Cl
B1b	Na-Ca-Mg-HCO_3-Cl
B2a	Na-Ca-HCO_3-Cl
B2b	Na-Ca-Mg-HCO_3-Cl

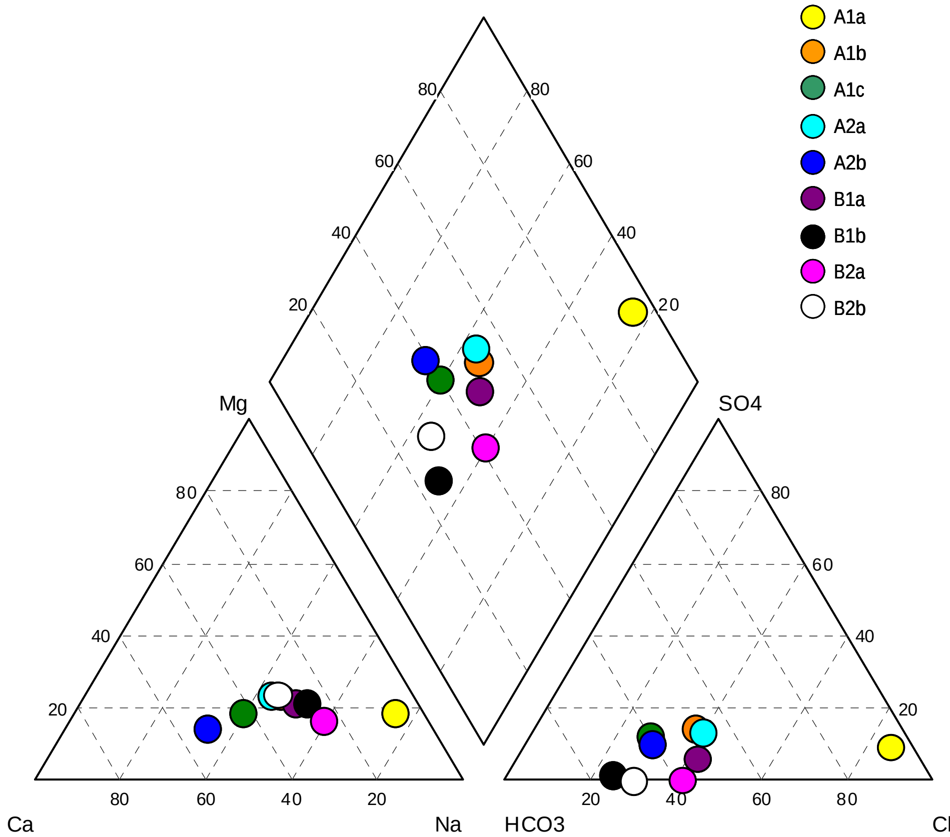


Figure 4.3: Piper diagram showing major ion ratios for the nine sub-clusters defined using Hierarchical Cluster Analysis (HCA) and Ward's methodology. HCA was conducted using median values (log transformed to the base ten) of 15 selected variables measured quarterly in 71 GQSoE bores between August 2005 and July 2010.

Table 4.1: Summary of hydrochemical cluster characteristics based on the median values (log transformed to the base ten) of 15 groundwater quality variables measured at 71 GQSoE bores between August 2005 and July 2010

Cluster	Description of water type at Threshold 3
A1a	Cluster A1a represents the groundwater chemistry of one bore (R25/5164) in an unconfined aquifer on the Kapiti Coast. This cluster has the lowest concentration of dissolved reactive silica (median 0.5 mg/L) and highest concentration of zinc (median 0.42 mg/L) compared to other clusters. Concentrations of sodium, chloride, potassium and bromide (medians of 29.9 mg/L, 55 mg/L, 2.86 mg/L and 0.17 mg/L, respectively) are moderate compared to other clusters suggesting that the groundwater is influenced by interaction with sea water.
A1b	Bores in cluster A1b tend to be located in the mid to lower reaches of the Hutt Valley, Wainuiomata, Kapiti Coast and western Wairarapa river catchments that drain mid-altitude un-weathered greywacke from the Tararua and Rimutaka ranges. Aquifers are generally unconfined to semi-confined and probably receive a mixture of recharge from rainfall and river drainage. Cluster A1b contains the largest number of GQSoE bores (19 of 71). Groundwater chemistry is associated with the greatest dissolved oxygen concentrations of all clusters except A1a, and lower concentrations of TDS (medians range 77.5–150 mg/L). Cluster A1b is also associated with a notable presence of nitrate (0.193–9 mg/L) and sulphate (1.9–13 mg/L) which suggests the groundwater is impacted by human activity. This is consistent with A1b bores being located in areas of the Wellington region that are most utilised for intensive land use (upper to mid Wairarapa Valley and the Kapiti Coast). However, concentrations of nitrate and sulphate remain fairly low due to high rates of dilution from river drainage.
A1c	Bores assigned to this cluster are associated with areas where there are high rates of river discharge to unconfined aquifers (upper Ruamahanga, lower Waingawa, lower Waiohine, lower Tauherenikau and Hutt Valley river catchments). Groundwater in this cluster has the lowest TDS (median range 49–83 mg/L) and major ion concentrations and second highest dissolved oxygen concentrations of all cluster groups. Concentrations of nitrate and sulphate (median range 0.27–2.7 mg/L and 3.3–10.65 mg/L) are generally the lowest of the A group clusters except A1a. The chemical signature cluster A1c is more typical of surface water chemistry, indicative of a strong hydraulic connection between groundwater and surface water.
A2a	Bores assigned to cluster A2a are differentiated from other A1 cluster bores by an increase in concentrations of all major ions. Cluster A2a is also defined by the highest nitrate concentrations of all cluster groups (median range 0.18–11 mg/L) and the second highest sulphate concentrations (median range 7.5–40.5 mg/L), suggestive of impacts on groundwater from human activity. Recharge of the groundwater is more likely by rainfall as increased concentrations of nitrate, TDS and major ions tend to accumulate in groundwater during the passage of groundwater through the soil zone. A2a bores are located in smaller catchments in the Hutt Valley, Te Ore Ore, lower Martinborough and the Kapiti Coast where intensive land use is present.
A2b	Cluster A2b bores are located on the eastern side of the Wellington region only where the groundwater chemistry is heavy influenced by carbonate-rich Miocene-Pliocene marine rocks. Recharge is most likely river-derived. Cluster A2b is associated with the greatest major ion and TDS concentrations of all the A group clusters, especially large increases in concentrations of bicarbonate (median range 121.5–270 mg/L) and calcium (median range 31.2–76 mg/L). Lower concentrations of nitrate (median range 0.2–3.27 mg/L) are likely due to the oxygen-poor receiving environment of the groundwater and associated de-nitrification processes.
B1a	Bores assigned to cluster B1a are generally located within semi-confined to confined aquifers of the Kapiti Coast and the mid to lower Wairarapa Valley (however, bore R25/5165 is located within the unconfined aquifer on the Kapiti Coast and is probably assigned to cluster B1a due to the higher concentrations of sodium and chloride recorded at this bore – which are comparable to the concentrations seen in other bores assigned to this cluster). Groundwater chemistry is similar to that of the A2 clusters (increased concentrations of major ions and TDS). However, lower concentrations of sulphate and dissolved oxygen, an absence of nitrate and increases in concentrations of iron, manganese and ammonia (median range 0.585–6.9 mg/L, 0.085–1.6 mg/L and 0.02–0.78 mg/L, respectively) suggest groundwater chemistry is influenced by oxygen-poor conditions within the aquifer. While rainfall is most likely the main source of groundwater recharge, groundwater may become more reduced with increased distance from the point of recharge.
B1b	Bores assigned to cluster B1b are located in semi-confined and confined aquifers in the sub-basins of Parkvale, Te Ore Ore, Huangarua, Battersea and at Somes Island. Groundwater chemistry has slightly lower concentrations of major ions compared to cluster B1a but increased concentrations of iron, manganese and ammonia (median range 0.09–3.5 mg/L, 0.063–0.82 mg/L and 0.017–0.44 mg/L, respectively) – this suggests groundwater recharge is originally from river drainage (except Battersea which is rainfall-recharged) but moves into an oxygen-poor environment within these aquifers (although conditions are not yet so reduced as to induce sulphate depletion).
B2a	Groundwater chemistry of the B2 clusters is associated with highest TDS and major ion concentrations, little or no sulphate, no nitrate and increased concentrations of total organic carbon, iron, manganese and ammonia (median range 1.1–6.96 mg/L, 0.8–8.11 mg/L, 0.15–1.4 mg/L and 0.29–7.9 mg/L, respectively). It is likely that aquifer recharge is via recharge though seepage from overlying aquifers or long residence through flow. The hydrochemistry of bores in cluster B2a is less evolved than cluster B2b and bores in this cluster are mainly located confined aquifers of the lower Wairarapa Valley. However, deep and highly confined bores (R25/5135, 93 m deep and S27/0442, 177 m deep) on the Kapiti Coast and mid Wairarapa Valley also fall into this cluster.
B2b	Cluster B2b represents the most reduced groundwater in the Wellington region. All three bores assigned to this cluster are located within confined aquifers in the lower Wairarapa Valley and have the highest concentrations of all variables for all cluster groups except nitrate, sulphate, dissolved oxygen (which have the lowest concentrations of all cluster groups). Cluster B2b is differentiated from cluster B2a by higher iron, manganese and ammonia concentrations (median range 6.85–16 mg/L, 1.4–1.5 mg/L, and 0.9–10.2 mg/L, respectively).

The Hutt Valley is also dominated by bores assigned to sub-clusters within Cluster A (Figure 4.4). Relatively low concentrations of TDS suggest groundwater is recharged by high volumes of river discharge from the Tararua and Rimutaka ranges (un-weathered greywacke) which results in lower concentrations of major ions. However, Hutt Valley aquifers become confined with increasing distance towards the Petone foreshore, and the hydrochemistry suggests a movement from oxygen-rich towards oxygen-poor groundwater conditions by Somes Island.

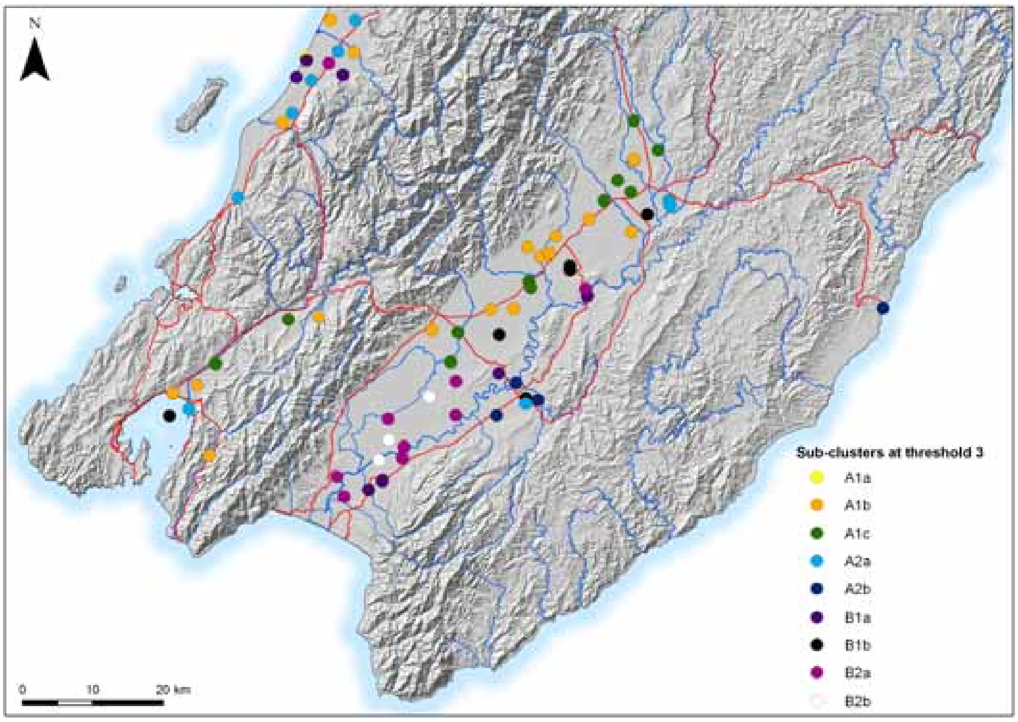


Figure 4.4: Hydrochemical classifications for the 71 GQSoE monitoring bores in the Wellington region, derived from hierarchical cluster analysis (HCA) based on the Ward's method, using median values (log transformed to the base ten) from 15 selected variables measured quarterly between August 2005 and July 2010

In the Wairarapa, a shift from oxygen-rich to oxygen-poor groundwater conditions can be seen with increased distance and confinement towards the lower Wairarapa Valley (Figure 4.4). Groundwater samples from bores assigned to sub-clusters within Cluster A are generally located in the upper to mid Wairarapa Valley; these sub-clusters are associated with low TDS due to high rates of input from river and rainfall recharge. The hydrochemistry of A1 and A2 sub-clusters is differentiated by higher concentrations of nitrate and sulphate in the A2 sub-clusters. It is likely that the impacts of human activity affect the groundwater quality in bores assigned to both sub-clusters, however, larger rates of river recharge keep concentrations of contaminants lower in bores assigned to the A1 sub-clusters. The hydrochemistry of sub-cluster A2b is influenced by the carbonate-rich lithology of the eastern hill country in the Wairarapa, whereas the hydrochemistry of A1 sub-clusters are influenced more by drainage from the un-weathered greywacke of the Tararua Range. The lower Wairarapa Valley is dominated by bores assigned to sub-clusters within the main Cluster B, ranging from moderate to highly reduced groundwater. However, it should be noted that there is little monitoring of unconfined aquifers in the lower Wairarapa Valley. Therefore, it is possible that reduction is only occurring in confined aquifers.

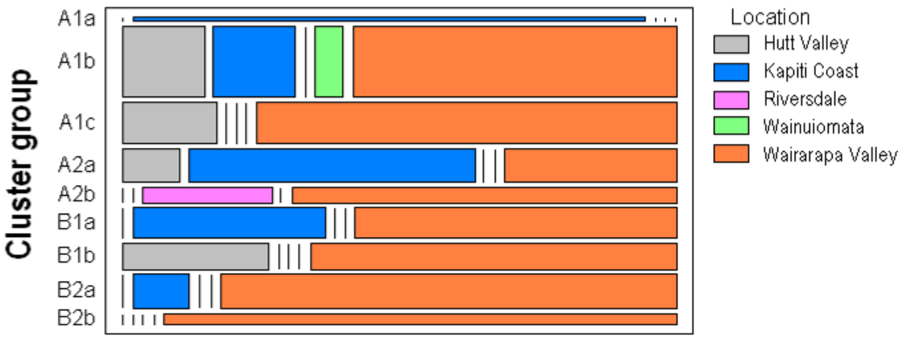
4.1.4 Cross-tabulation

Further analysis using cross-tabulation was conducted to explore the relationships between the hydrochemistry of each sub-cluster and aquifer confinement, bore location, lithology and overlying landuse (Figure 4.5). The results suggest that hydrochemical differences between sub-clusters can be related to aquifer lithology and confinement; both of these relationships were confirmed as being statistically significant ($p<0.05$) using the Chi-square test.

The significant relationship between hydrochemistry and aquifer confinement is to be expected given that the majority of unconfined aquifers fall into sub-clusters within Cluster A, which have water chemistry more typical of oxygen-rich environments. Bores located in aquifers classed as confined dominated the sub-clusters within Cluster B, which display hydrochemistry more typical of an oxygen-poor environment.

The significant relationship between hydrochemistry and aquifer lithology suggests that sites assigned to sub-clusters within Cluster A are more prevalent in gravel lithology. The sub-clusters within Cluster B are not clearly related to aquifer lithology, except that the most reduced groundwater occurs in bores screened in sand or silt lithologies. This is consistent with a New Zealand-wide study that showed that, compared to gravels, aquifers comprising sand and silt often have greater abundance of the organic materials that promote the onset of oxygen-poor conditions (Daughney 2003).

Although HCA clearly indicated that human activity influences groundwater quality – evident through elevated concentrations (relative to background) of nitrate and sulphate in some bores – cross-tabulation did not identify a statistically significant relationship between sub-cluster hydrochemistry and bore location, or between sub-cluster hydrochemistry and overlying land use. This is not overly surprising. An independent study of New Zealand's groundwater chemistry (Daughney & Reeves 2005) also noted the lack of a statistically significant relationship between hydrochemistry, bore location and land use. While this may reflect the lack of resolution in HCA to differentiate between the impacts from different land uses (eg, horticulture vs high producing pasture), it probably also suggests that overlying land use at the bore location may not directly affect groundwater quality recorded at that particular bore; land use practices in the recharge zone (which may be some distance from the sampling bore) are probably more influential. Other possible reasons that could contribute to the lack of a statistically significant relationship between hydrochemistry, bore location and land use include degradation or transformation of variable concentration before reaching the sampling bore, land use information surrounding the bore being incorrect or a time lag between the contaminant entering the groundwater system and being detected in a sampling bore (Daughney & Reeves 2005).



Tests of Independence

Test	*Statistic*	*Df*	*P-Value*
Chi-Squared	45.717	32	0.0550

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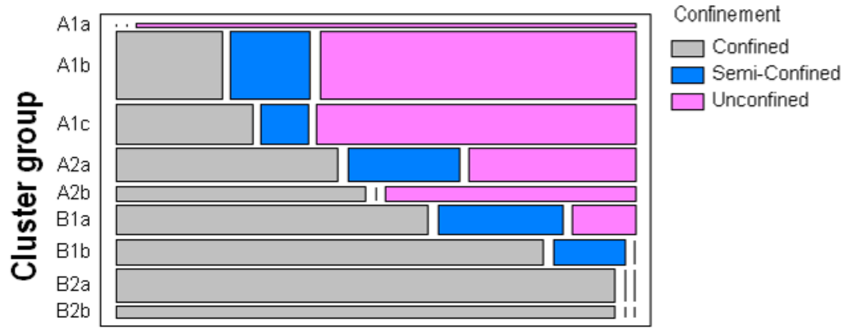

Tests of Independence

Test	*Statistic*	*Df*	*P-Value*
Chi-Squared	32.152	16	0.0096

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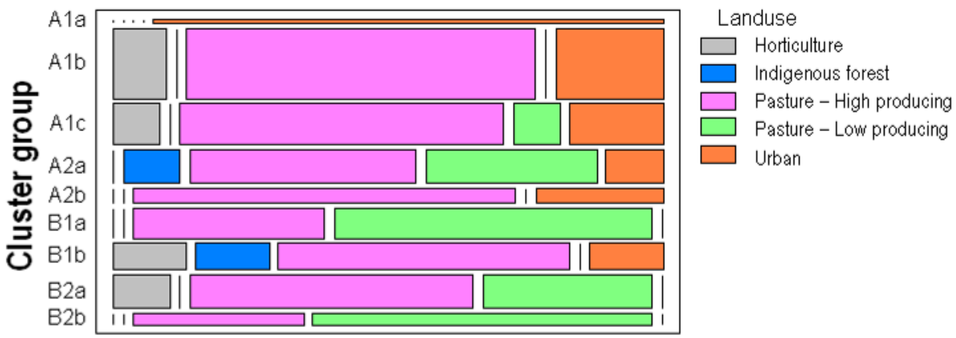

Tests of Independence

Test	*Statistic*	*Df*	*P-Value*
Chi-Squared	40.776	32	0.1374

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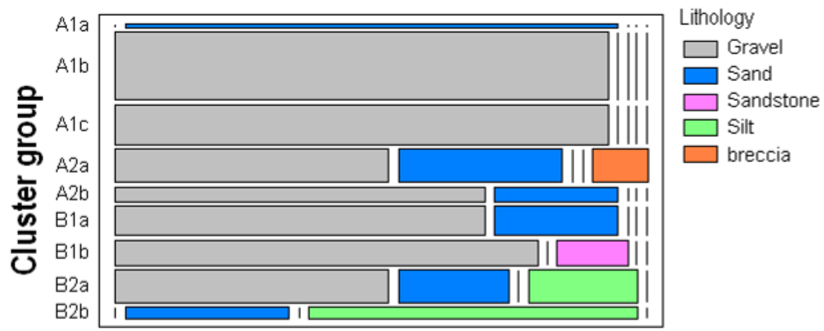


Tests of Independence

Test	*Statistic*	*Df*	*P-Value*
Chi-Squared	64.886	32	0.0005

Warning: some expected cell counts < 5.

Figure 4.5: Cross-tabulation plots showing relationships between the nine sub-clusters defined by HCA and bore location, aquifer confinement, overlying landuse and aquifer lithology. Chi-square tests confirmed a statistically significant (p<0.05) relationship between sub-cluster hydrochemistry and aquifer confinement, and sub-cluster hydrochemistry and aquifer lithology.

4.2 Current state

In this section descriptive statistics are presented for selected groundwater quality variables (see Appendix 4 for the complete list of summary statistics). Results are evaluated against relevant DWSNZ (2005) and ANZECC (2000) guideline values.

4.2.1 Approach to analysis

Although GQSoE samples are routinely tested for 31 variables, this section focuses on summarising the current state of groundwater quality across the Wellington region using a subset of nine key variables. The variables selected include those used in recent national level groundwater quality reporting by Daughney and Randall (2009) and are considered indicators of human impact, human/ecological health risk, or indicators of natural groundwater chemistry (Table 4.2). Supplementary data from recent one-off heavy metal and metalloid sampling and regional pesticide surveys are also included in this section to assist with characterising the overall state of groundwater quality.

Descriptive statistics were derived for each of the nine variables using R Package V 2.12.0 (The R Foundation for Statistical Computing 2010), with median values compared against relevant national water quality standards and guidelines (see Section 4.2.1 (a)). Summary statistics for the remaining 22 variables are presented in Appendix 4.

(a) Data adjustment and presentation

Where a data set for a variable contained values below the laboratory's analytical detection limit (ie, censored values), statistical analysis was carried out using the NADA (Non-detects and Data Analysis) for R Package which contains S-language implementations of the methods described by Helsel (2005). Essentially:

- Where the data set had greater than 70% censored values, the median and minimum values were reported as the laboratory detection limit (Helsel & Cohn 1988); and
- Where a data set had less than 70% censored values the summary statistic values were calculated using regression on ordered statistics (ROS) as implemented in the NADA for R Package and described by Helsel (2005).

In terms of bacteriological data, which are expressed as counts of colony forming units per 100 mL, censored values have been reported as the laboratory detection limit for median and minimum values where the data set had greater than 70% censored values.

Table 4.2: Key indicator variables used to summarise the current state of groundwater quality in the Wellington region. Relevant guideline values (GV), maximum acceptable values (MAV) and trigger values (TV) are also outlined.

(Source: After Daughney & Randall 2009)

Variable	Explanation for inclusion as a key variable
Total dissolved solids (TDS)	TDS can provide a useful indicator for spatial and/or temporal changes in abstraction, salt water intrusion, recharge mechanism, etc. Although there are no recognised health or ecosystem risks associated with elevated TDS concentrations in drinking water, the DWSNZ (2005) includes an aesthetic GV of 1,000 mg/L (taste threshold) and ANZECC (2000) contain a stockwater threshold of 2,000–2,500 mg/L (the point at which productivity of stock drinking the water may decline).
Nitrite nitrogen (Nitrite)	Consumption of groundwater with excessive concentrations of nitrite can adversely affect human and stock health. The DWSNZ (2005) and ANZECC (2000) specify a MAV of 0.06 mg/L and a stockwater TV of 30 mg/L for nitrite respectively.
Nitrate nitrogen (Nitrate)	Nitrate is routinely monitored for health and environmental reasons. Consumption of groundwater with excessive concentrations of nitrate can adversely affect human (and stock) health, and elevated concentrations of nitrate in groundwater can contribute to eutrophication of surface waters. The DWSNZ (2005) specify a MAV of 11.3 mg/L for nitrate while the ANZECC (2000) guidelines specify a TV of 0.444 mg/L for lowland streams for nitrite nitrate nitrogen (NNN) – while this is typically used as a threshold when reporting on surface water and ecological quality, a recently revised nitrate threshold of 1.7 mg/L (Hickey & Martin 2009)[1] is used here as it is more directly relevant for assessing aquatic toxicity.
Ammoniacal nitrogen (Ammonia)	In the absence of nitrate[2] in the groundwater chemical profile, ammonia can show whether land use is having an impact on groundwater quality, or if the natural conditions in the aquifer makes detection of land use impacts difficult. The DWSNZ (2005) specifies a GV of 1.5 mg/L and ANZECC (2000) specifies a lowland river TV of 0.021 mg/L. ANZECC (2000) also specifies thresholds for aquatic toxicity; although these TVs vary with pH, for simplicity of reporting, the default toxicity TV (95% species protection level and applicable at pH 8.0) of 0.9 mg/L has been used here.
Iron (Fe)	There are no recognised health or ecosystem risks associated with groundwater enriched with dissolved iron but elevated concentrations in groundwater may indicate the possible occurrence of arsenic (Smedley & Kinniburgh 2002), which is not routinely monitored in groundwater in the Wellington region. Iron is only soluble under oxygen-poor conditions, so complements the interpretation of ammonia and nitrate concentrations in groundwater. The DWSNZ (2000) lists an aesthetic GV for iron of 0.2 mg/L (taste threshold).
Manganese (Mn)	Due to risks to human health and freshwater ecosystems, the DWSNZ (2005) specifies a MAV of 0.4 mg/L and the ANZECC (2000) guidelines include an aquatic toxicity TV (95% species protection level) of 1.9 mg/L. The DWSNZ (2005) also includes an aesthetic GV of 0.04 mg/L (taste threshold and prevention of staining of laundry and whiteware). Like iron, manganese is only soluble in oxygen-poor groundwater and so can aid the understanding of measured concentrations of nitrate.
Fluoride	Consumption of groundwater with excessive concentrations of fluoride can adversely affect human and stock health. The DWSNZ (2005) and ANZECC (2000) specify a MAV of 1.5 mg/L and a stockwater TV of 2 mg/L for fluoride respectively.
Lead	Consumption of groundwater with excessive concentrations of lead can adversely affect human and aquatic ecosystem health. The DWSNZ (2005) and ANZECC (2000) specify a MAV of 0.1 mg/L and an aquatic toxicity TV (95% species protection level) of 0.0034 mg/L for lead respectively.
Escherichia coli (*E. coli*)	*E. coli* is a species of bacteria that indicates the presence of faecal matter in groundwater. The DWSNZ (2005) and ANZECC (2000) specify a MAV of <1 cfu/100mL and a stockwater TV (median) of 100 cfu/100mL for *E. coli* respectively.

[1] This value is a recommended replacement value for the current ANZECC (2000) toxicity TV of 7.2 mg/L.

[2] In general nitrate nitrogen exists as ammoniacal nitrogen in oxygen-poor conditions; conversion between the two nitrogen species can be induced by natural processes such as reduction (removal of oxygen from groundwater) or microbially driven reactions.

Box-and-whisker plots (box plots) generated in Sigmaplot (v11.0) are used to show the median and range of results for the nine selected GQSoE indicator variables. In terms of interpretation:

- The lower and upper boundaries of the box represent the 25th percentile and 75th percentile of the data set respectively (a minimum of three data points are needed to generate the box);
- The horizontal line within the box represents the median value;
- The 'whiskers' (error bars) extending above and below the box (inter-quartile range) represent the 90th and 10th percentile values respectively; and
- The black dots represent outliers.

Note that where median values are presented graphically, those values represented by laboratory detection limits have been made numeric by removing the '<' symbol.

(b) Water quality guidelines

Groundwater sample results were compared against the Drinking Water Standard for New Zealand (DWSNZ 2005). This standard applies to water used for human consumption and sets a health-related maximum acceptable value (MAV) or an aesthetic guideline value (GV) for a number of variables. The MAVs and GVs used are outlined in Table 4.2.

Similar to the approach adopted in recent national level groundwater quality reporting (Daughney & Randall 2009), groundwater results were also compared against selected ANZECC (2000) trigger values for aquatic toxicity (and livestock drinking water) that are more commonly applied to surface waters (see Table 4.2). This is because shallow groundwater is known to discharge into a number of surface water bodies in the Wellington region, with potential for adverse ecological effects where groundwater nutrient or other contaminant concentrations are high. It is recognised that using these trigger values as a direct comparison assumes that groundwater makes up the entire surface water flow. In reality, there will be some dilution of groundwater by surface water[14].

Groundwater nitrate nitrogen (nitrate) concentrations were also evaluated in terms of likely human influence since groundwater in New Zealand rarely has nitrate concentrations above 1 mg/L naturally (Close et al. 2001). A threshold of 3 mg/L was adopted as a means of defining nitrate contamination from anthropogenic sources (Close et al. 2001). This threshold, which is similar to the 3.5 mg/L 'almost certainly human influence' threshold defined by Daughney and Reeves (2005)[15], has been used by Greater Wellington in previous reporting (eg, Tidswell 2009, Milne et al. 2010) and follows the findings of a US study of nitrates (Madison & Brunett 1985) that concluded concentrations of nitrate in

[14] Although, according to Dr Chris Daughney (GNS Science, pers. comm. 2012), it is not uncommon for groundwater to supply 80% of baseflow at low flow conditions.

[15] Daughney and Reeves (2005) also concluded that nitrate concentrations above 1.6 mg/L are 'probably' indicative of human influence.

groundwater above 3 mg/L were due to human influence. In this section, reference to 'elevated' nitrate concentrations indicates the concentrations are above 3 mg/L; an additional 'highly elevated' threshold was arbitrarily set at >7 mg/L, approximately mid-way between the elevated threshold and the DWSNZ MAV of 11.3 mg/L.

E. coli indicator bacteria results were compared against both the DWSNZ (2005) and the ANZECC (2000) stockwater trigger value. This is because some of the groundwater bores in the GQSoE programme are used for potable supply and others are used for stockwater supply.

4.2.2 Key groundwater quality indicator variables

(a) Total dissolved solids

Median TDS concentrations ranged from 49 mg/L to 760 mg/L (Table 4.3), well below the DWSNZ (2005) and the ANZECC (2000) stockwater guideline values. TDS concentrations were generally lower in bores assigned to A group clusters, nearer sources of surface water recharge and in unconfined to semi-confined aquifers. In contrast, greater median TDS values were recorded in bores assigned to B group clusters, bores located in deeper semi-confined and confined aquifers, and in bores located in Kapiti, the Wairarapa Valley (B group bores) and Riversdale (saline influence) (Figure 4.6).

Bores R27/1171, R27/1180 and R27/1183, which are all located in the confined Waiwhetu aquifer in the Hutt Valley, recorded median TDS concentrations lower than those in similar aquifer types in other parts of the region. This can probably be attributed to the Hutt River which recharges the Waiwhetu aquifer before it becomes confined. HCA analysis indicated that the bores in the Hutt Valley are mostly assigned to A groups sub-clusters; the exception is bore R27/1171 (Somes Island) which displays hydrochemical characteristics of an oxygen-poor environment (although the water is originally sourced from river recharge).

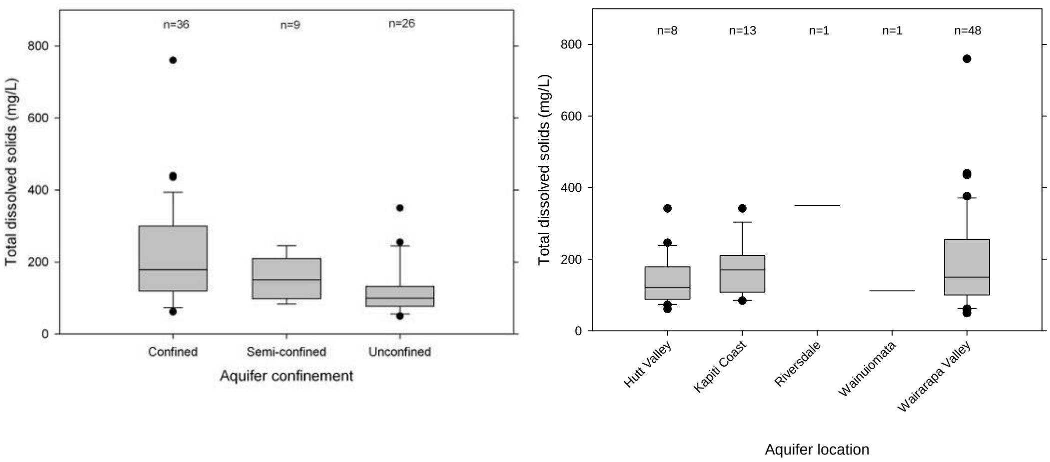


Figure 4.6: Box plots of median TDS concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped according to both aquifer confinement (left) and aquifer location (right)

Table 4.3: Median (and range as 5th and 95th percentiles) concentrations of nine key variables measured quarterly in 71 GQSoE bores in the Wellington region over the period 1 August 2005 to 31 July 2010. Bolded median values exceed the relevant DWSNZ (2005) MAV or TV while italicised median values exceed the ANZECC (2000) aquatic toxicity TV (refer Table 4.2). The values presented have been determined employing the NADA approach as outlined in Section 4.2.1(a), the exception being where NADA assigned a value of zero (in which case a value one half of the detection limit was substituted).

Site	Total dissolved solids (mg/L)			Nitrite nitrogen (mg/L)			Nitrate nitrogen (mg/L)			Ammoniacal nitrogen (mg/L)			Dissolved iron (mg/L)			Dissolved manganese (mg/L)			Fluoride (mg/L)			Dissolved lead (mg/L)			*E. coli* (cfu/100mL)		
	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*
Kapiti Coast																											
R25/5100	210	200 – 228	20	0.001	<0.002 – 0.007	20	<0.002	<0.002 – 0.008	20	0.18	0.16 – 0.21	20	1.59	0.57 – 6.39	20	1.600	1.395 – 1.704	20	0.13	0.10 – 0.14	20	<0.0001	<0.0001	20	<1	<1 – 1	20
R25/5135	342	330 – 351	19	<0.002	<0.002	19	0.002	0.001 – 0.004	19	0.29	0.26 – 0.34	19	0.80	0.57 – 1.11	19	0.860	0.777 – 0.946	19	0.09	0.06 – 0.10	19	<0.0001	<0.0001 – 0.0001	19	*Not tested*		
R25/5164	120	78.4 – 190	19	<0.002	<0.002 – 0.003	19	0.410	0.274 – 0.818	19	0.01	<0.01 – 0.05	19	0.03	<0.02 – 0.08	19	0.011	0.002 – 0.033	19	<0.05	<0.05 – 0.06	19	0.0004	0.0002 – 0.0007	19	37	2 – 3,000	19
R25/5165	130	86.7 – 159	19	0.002	0.001 – 0.005	19	0.016	0.002 – 0.427	19	0.24	0.15 – 0.30	19	2.89	1.60 – 3.53	19	0.085	0.048 – 0.102	19	0.18	0.14 – 0.21	19	0.0010	0.0006 – 0.0020	19	<1	<1	19
R25/5190	210	188 – 246	20	0.001	<0.002 – 0.028	20	*5.09*	3.60 – 8.53	20	0.03	0.01 – 0.06	20	<0.02	<0.02	20	0.022	0.001 – 0.043	20	0.09	0.06 – 0.10	20	0.0001	0.0001 – 0.0002	20	<1	<1 – 3	20
R25/5233	96.0	77.6 – 150	20	<0.002	<0.002	20	1.60	1.11 – 2.00	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02	20	<0.0005	<0.0005 – 0.001	20	0.06	0.04 – 0.08	20	0.0002	<0.0001 – 0.0008	20	<1	<1	20
R26/6503	178	150 – 190	20	<0.002	<0.002 – 0.003	20	0.018	0.007 – 0.201	20	0.01	<0.01 – 0.11	20	0.07	<0.02 – 1.61	20	0.013	0.009 – 0.050	20	0.13	0.10 – 0.16	20	<0.0001	<0.0001 – 0.0003	20	*Not tested*		
R26/6587	84.0	74.6 – 102	17	<0.002	<0.002	17	0.670	0.404 – 1.25	17	<0.01	<0.01 – 0.02	17	0.02	0.01 – 0.03	17	0.002	0.001 – 0.006	17	0.07	0.05 – 0.11	17	<0.0001	<0.0001 – 0.0004	17	<1	<1	17
R26/6624	150	130 – 160	19	<0.002	<0.002	19	*2.90*	2.44 – 3.43	19	<0.01	<0.01 – 0.03	19	<0.02	<0.02 – 0.28	19	<0.0005	<0.0005 – 0.138	19	0.17	0.15 – 0.23	19	0.0001	<0.0001 – 0.0004	19	<1	<1 – 10	19
S25/5125	87.0	70.0 – 130	21	<0.002	<0.002	21	*2.60*	0.850 – 4.40	21	<0.01	<0.01 – 0.02	21	<0.02	<0.02 – 0.04	21	<0.0005	<0.0005 – 0.001	21	0.09	0.06 – 0.12	21	0.0003	0.0001 – 0.0010	21	<1	<1 – 4	21
S25/5200	180	162 – 186	18	<0.002	<0.002	18	0.003	0.001 – 0.008	18	0.02	0.02 – 0.03	18	0.59	0.27 – 1.07	18	0.940	0.818 – 1.112	18	0.25	0.23 – 0.28	18	<0.0001	<0.0001 – 0.0001	18	<1	<1	18
S25/5256	170	159 – 192	19	<0.002	<0.002	19	*9.60*	8.46 – 10.5	19	<0.01	<0.01 – 0.03	19	<0.02	<0.02 – 0.02	19	0.001	<0.0005 – 0.003	19	0.16	0.15 – 0.18	19	0.0001	<0.0001 – 0.0008	19	*Not tested*		
S25/5322	246	230 – 260	21	<0.002	<0.002 – 0.003	21	*9.90*	9.40 – 11.0	21	<0.01	<0.01 – 0.05	21	<0.02	<0.02	21	<0.0005	<0.0005 – 0.002	21	0.08	0.07 – 0.09	21	0.0002	0.0001 – 0.0005	21	<1	<1 – 4	21
Hutt Valley																											
R27/0320	120	106 – 127	20	<0.002	<0.002 – 0.003	20	0.001	<0.002 – 0.013	20	0.12	0.10 – 0.15	20	0.09	0.08 – 0.19	20	0.063	0.057– 0.070	20	0.14	0.12 – 0.16	20	<0.0001	<0.0001 – 0.0001	20	*Not tested*		
R27/1137	72.5	56.5 – 93.1	20	<0.002	<0.002 – 0.004	20	1.04	0.483 – 1.81	20	<0.01	<0.01 – 0.02	20	0.07	0.01 – 0.48	20	0.004	<0.0005 – 0.024	20	0.06	0.04 – 0.11	20	<0.0001	<0.0001 – 0.0002	20	<1	<1 – 6	20
R27/1171	95.5	92.0 – 100	16	<0.002	<0.002	16	<0.002	<0.002 – 0.009	16	0.34	0.28 – 0.36	16	1.25	1.20 – 1.52	16	0.240	0.218 – 0.276	16	0.17	0.14 – 0.20	16	<0.0001	<0.0001 – 0.0004	16	*Not tested*		
R27/1180	89.5	76.8 – 96.1	20	<0.002	<0.002 – 0.004	20	0.848	0.727 – 1.10	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02	20	<0.0005	<0.0005 – 0.001	20	0.06	0.04 – 0.08	20	0.0007	0.0004 – 0.0018	20	*Not tested*		
R27/1182	123	112 – 141	20	0.010	0.008 – 0.012	20	0.801	0.730 – 0.850	20	<0.01	<0.01 – 0.01	20	0.19	0.15 – 0.24	20	0.057	0.050 – 0.061	20	0.08	0.06 – 0.11	20	<0.0001	<0.0001 – 0.0002	20	*Not tested*		
R27/1183	61.0	44.9 – 68.3	20	<0.002	<0.002	20	0.313	0.238 – 0.466	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02 – 0.03	20	<0.0005	<0.0005 – 0.001	20	0.06	0.05 – 0.08	20	0.0003	0.0002 – 0.0005	20	<1	<1 – 3	20
R27/1265	77.5	65.9 – 94.4	20	<0.002	<0.002	20	0.200	0.141 – 0.220	20	0.01	<0.01 – 0.06	20	0.19	0.11 – 0.48	20	0.021	0.017 – 0.041	20	0.17	0.14 – 0.19	20	<0.0001	<0.0001 – 0.0001	20	*Not tested*		
R27/6833	120	102.4 – 130	20	<0.002	<0.002 – 0.005	20	0.570	0.266 – 1.43	20	<0.01	<0.01 – 0.04	20	<0.02	<0.02 – 0.04	20	0.255	0.150 – 0.371	20	0.18	0.13 – 0.19	20	<0.0001	<0.0001 – 0.0003	20	<1	<1 – 4	20
Wainuiomata																											
R27/6418	112	94.9 – 130	20	<0.002	<0.002	20	*1.74*	0.934 – 2.98	20	<0.01	<0.01 – 0.03	20	<0.02	<0.02 – 0.02	20	0.001	0.001 – 0.002	20	0.06	0.04 – 0.08	20	0.0004	0.0002 – 0.0013	20	<1	<1 – 60	19
Wairarapa Valley																											
S26/0117	97.5	81.6 – 116	20	<0.002	<0.002 – 0.003	20	*3.40*	2.18 – 7.10	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02	20	0.001	<0.0005 – 0.002	20	0.07	0.05 – 0.1	20	0.0002	<0.0001 – 0.0006	20	<1	1 – 80	19
S26/0223	140	93.6 – 164	20	<0.002	<0.002	20	*9.15*	5.62 – 11.7	20	<0.01	<0.01 – 0.03	20	<0.02	<0.02	20	0.001	0.001 – 0.004	20	0.05	0.04 – 0.08	20	0.0004	0.0003 – 0.0007	20	<1	<1 – 2	20
S26/0299	78.0	64.4 – 102	19	<0.002	<0.002	19	*2.70*	2.07 – 4.63	19	<0.01	<0.01 – 0.01	19	<0.02	<0.02	19	0.002	0.001 – 0.003	19	0.02	<0.05 – 0.09	19	0.0004	0.0003 – 0.0006	19	<1	<1 – 22	19
S26/0439	113	99.4 – 130	20	<0.002	<0.002	20	*3.50*	3.05 – 3.99	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02 – 0.03	20	0.001	0.001 – 0.007	20	0.10	0.08 – 0.11	20	0.0003	0.0001 – 0.0005	20	<1	<1 – 840	19
S26/0457	50.0	42.6 – 69.6	18	<0.002	<0.002	18	0.432	0.237 – 1.53	18	<0.01	<0.01 – 0.02	18	<0.02	<0.02	18	0.001	0.001 – 0.001	18	0.04	0.02 – 0.08	18	<0.0001	<0.0001 – 0.0001	18	<1	<1	18
S26/0467	89.0	78.5 – 100	20	<0.002	<0.002	20	*2.00*	1.30 – 3.63	20	<0.01	<0.01 – 0.03	20	<0.02	<0.02	20	0.001	<0.0005 – 0.004	20	0.07	0.06 – 0.08	20	0.0001	0.0001 – 0.0002	20	<1	<1 – 2	19
S26/0568	174	160 – 190	20	0.004	0.002 – 0.006	20	<0.002	<0.002 – 0.021	20	0.44	0.41 – 0.49	20	3.50	3.03 – 3.80	20	0.823	0.760 – 0.914	20	0.11	0.10 – 0.22	20	<0.0001	<0.0001	20	*Not tested*		
S26/0576	150	134 – 166	18	<0.002	<0.002	18	0.004	<0.002 – 0.088	18	0.37	0.31 – 0.52	18	1.35	0.10 – 3.22	18	0.605	0.558 – 0.682	18	0.11	0.09 – 0.15	18	<0.0001	<0.0001	18	*Not tested*		
S26/0705	120	110 – 128	20	<0.002	<0.002	20	*4.84*	4.68 – 5.29	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02 – 0.02	20	0.001	<0.0005 – 0.001	20	0.15	0.14 – 0.16	20	0.0002	<0.0001 – 0.0006	20	<1	<1	17
S26/0756	177	153 – 191	18	0.004	0.002 – 0.01	18	0.004	<0.002 – 0.023	18	0.08	0.03 – 0.25	18	2.65	2.12 – 3.35	18	0.940	0.816 – 1.212	18	0.07	0.05 – 0.09	18	<0.0001	<0.0001 – 0.0002	18	*Not tested*		
S26/0762	200	180 – 220	20	0.006	0.003 – 0.01	20	0.003	0.001 – 0.008	20	0.51	0.46 – 0.54	20	7.48	5.74 – 8.51	20	0.898	0.776 – 1.052	20	0.19	0.16 – 0.21	20	<0.0001	<0.0001 – 0.0001	20	<1	<1 – 12	20
S26/0824	124	110 – 132	20	<0.002	<0.002	20	*5.30*	4.87 – 6.32	20	<0.01	<0.01 – 0.06	20	<0.02	<0.02 – 0.02	20	0.001	0.001 – 0.003	20	0.12	0.09 – 0.14	20	0.0002	<0.0001 – 0.0006	20	<1	<1	18
S26/0846	61.0	49.0 – 72.0	21	<0.002	<0.002	21	0.658	0.530 – 0.960	21	<0.01	<0.01 – 0.01	21	0.04	0.01 – 0.15	21	0.004	0.003 – 0.008	21	0.05	0.03 – 0.08	21	<0.0001	<0.0001 – 0.0003	21	*Not tested*		
S27/0009	110	96.4 – 122	20	<0.002	<0.002	20	*2.95*	2.40 – 4.28	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02 – 0.02	20	<0.0005	<0.0005 – 0.005	20	0.07	0.05 – 0.09	20	<0.0001	<0.0001 – 0.0002	20	<1	<1 – 3	20
S27/0070	49.0	41.6 – 86.3	19	<0.002	<0.002	19	0.454	0.174 – 2.41	19	<0.01	<0.01 – 0.02	19	<0.02	<0.02 – 0.02	19	0.001	0.001 – 0.002	19	<0.05	<0.05 – 0.07	19	0.0004	0.0002 – 0.0007	19	<1	<1	19
S27/0136	100	68.3 – 130	19	0.002	<0.002 – 0.01	19	*5.42*	1.87 – 7.38	19	0.01	0.001 – 0.12	19	0.04	0.01 – 0.23	19	0.016	0.011 – 0.082	19	0.06	0.04 – 0.08	19	<0.0001	<0.0001 – 0.0002	19	<1	1 – 39	19
S27/0156	100	86.8 – 110	19	<0.002	<0.002	19	0.003	<0.002 – 0.028	19	0.02	<0.001 – 0.06	19	0.35	0.13 – 0.48	19	0.332	0.290 – 0.384	19	0.24	0.20 – 0.26	19	<0.0001	<0.0001	19	<1	<1 – 100	19
S27/0202	98.5	80.7 – 111	20	<0.002	<0.002	20	*3.52*	2.49 – 4.64	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02 – 0.02	20	0.002	0.002 – 0.005	20	0.07	0.06 – 0.09	20	<0.0001	<0.0001 – 0.0002	20	<1	1 – 700	20
S27/0268	350	327 – 361	20	<0.002	<0.002 – 0.003	20	0.001	<0.002 – 0.02	20	*0.97*	0.71 – 1.1	20	6.85	5.06 – 8.42	20	1.500	1.300 – 1.675	20	0.06	0.05 – 0.08	20	<0.0001	<0.0001 – 0.0001	20	*Not tested*		
S27/0283	180	159 – 198	17	0.014	0.003 – 0.04	17	0.001	<0.002 – 0.015	17	0.88	0.79 – 0.97	17	8.11	7.30 – 10.3	17	0.510	0.457 – 0.595	17	0.19	0.18 – 0.22	17	<0.0001	<0.0001 – 0.0003	17	*Not tested*		
S27/0299	62.5	54.0 – 72.3	20	<0.002	<0.002	20	0.265	0.223 – 0.311	20	<0.01	<0.01 – 0.02	20	0.03	0.02 – 0.05	20	0.001	<0.0005 – 0.001	20	0.08	0.06 – 0.10	20	0.0003	0.0001 – 0.0009	20	<1	<1	18
S27/0344	190	170 – 213	18	<0.002	<0.002	18	0.003	0.001 – 0.008	18	0.08	0.07 – 0.12	18	0.93	0.80 – 1.10	18	0.476	0.438 – 0.528	18	0.13	0.11 – 0.15	18	<0.0001	<0.0001	18	<1	<1	16
S27/0389	140	125 – 150	20	<0.002	<0.002 – 0.008	20	<0.002	<0.002 – 0.574	20	0.12	0.07 – 0.16	20	0.11	0.04 – 0.20	20	0.434	0.390 – 0.511	20	0.48	0.42 – 0.53	20	<0.0001	<0.0001 – 0.0001	20	<1	<1 – 34	20
S27/0396	310	200 – 334	19	<0.002	<0.002	20	0.218	0.040 – 0.781	19	<0.01	<0.01 – 0.01	19	0.04	0.01 – 0.12	19	0.052	0.012 – 0.082	19	0.10	0.08 – 0.17	19	0.0003	<0.0001 – 0.0045	19	<1	<1 – 4	19

Table 4.3 *cont.*: Median (and range as 5th and 95th percentiles) concentrations of nine key variables measured quarterly in 71 GQSoE bores in the Wellington region over the period 1 August 2005 to 31 July 2010. Bolded median values exceed the relevant DWSNZ (2005) MAV or TV while italicised median values exceed the ANZECC (2000) aquatic toxicity TV (refer Table 4.2). The values presented have been determined employing the NADA approach as outlined in Section 4.2.1(a), the exception being where NADA assigned a value of zero (in which case a value one half of the detection limit was substituted).

Site	Total dissolved solids (mg/L)			Nitrite nitrogen (mg/L)			Nitrate nitrogen (mg/L)			Ammoniacal nitrogen (mg/L)			Dissolved iron (mg/L)			Dissolved manganese (mg/L)			Fluoride (mg/L)			Dissolved lead (mg/L)			*E. coli* (cfu/100mL)		
	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*	Median	Range	*n*
S27/0433	435	404 – 450	19	0.001	<0.002 – 0.033	19	<0.002	<0.002 – 0.009	19	*7.30*	6.69 – 7.88	19	12.6	11.0 – 14.2	19	1.600	1.390 – 1.814	19	0.18	0.16 – 0.20	19	<0.0001	<0.0001 – 0.0001	19	*Not tested*		
S27/0435	212	190 – 222	20	<0.002	<0.002	20	<0.002	<0.002 – 0.006	20	*7.90*	7.55 – 8.51	20	6.55	5.80 – 7.11	20	0.494	0.428 – 0.543	20	0.30	0.28 – 0.33	20	<0.0001	<0.0001 – 0.0002	20	*Not tested*		
S27/0442	370	358 – 384	20	<0.002	<0.002	20	<0.002	<0.002 – 0.003	20	*0.94*	0.86 – 1.02	20	1.17	0.74 – 1.70	20	0.150	0.130 – 0.176	20	0.49	0.46 – 0.53	20	<0.0001	<0.0001 – 0.0001	20	*Not tested*		
S27/0495	376	316 – 446	19	0.002	0.001 – 0.015	19	0.003	<0.002 – 0.033	19	*1.90*	1.70 – 2.16	19	4.90	4.18 – 6.90	19	0.780	0.655 – 1.084	19	0.18	0.16 – 0.19	19	<0.0001	<0.0001	19	*Not tested*		
S27/0522	440	414 – 463	20	<0.002	<0.002 – 0.003	20	*3.28*	3.00 – 3.47	20	<0.01	<0.01 – 0.16	20	0.02	<0.02 – 0.12	20	0.003	0.001 – 0.025	20	0.29	0.28 – 0.37	20	<0.0001	<0.0001 – 0.0002	20	<1	<1 – 4	20
S27/0571	185	158 – 210	20	<0.002	<0.002	20	*9.22*	7.93 – 10.1	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02 – 0.14	20	0.004	0.002 – 0.011	20	0.25	0.23 – 0.28	20	0.0001	<0.0001 – 0.0004	20	<1	<1 – 4	19
S27/0585	270	259 – 280	19	0.003	0.001 – 0.006	19	<0.002	<0.002 – 0.003	19	0.63	0.51 – 0.76	19	1.44	1.29 – 8.54	19	1.400	1.280 – 1.555	19	0.54	0.48 – 0.60	19	<0.0001	<0.0001 – 0.0002	19	*Not tested*		
S27/0588	110	95.8 – 120	20	0.004	0.002 – 0.007	20	0.003	0.001 – 0.007	20	0.09	0.08 – 0.11	20	4.60	4.20 – 4.82	20	0.140	0.130 – 0.150	20	0.09	0.08 – 0.12	20	<0.0001	<0.0001 – 0.0003	20	<1	<1	19
S27/0594	310	301 – 320	17	<0.002	<0.002	17	<0.002	<0.002 – 0.009	17	0.73	0.66 – 0.77	17	1.70	1.62 – 1.90	17	0.250	0.228 – 0.281	17	0.26	0.24 – 0.28	17	<0.0001	<0.0001 – 0.0001	17	*Not tested*		
S27/0602	260	250 – 270	19	<0.002	<0.002	19	<0.002	<0.002 – 0.004	19	*2.60*	2.13 – 2.74	19	3.30	2.88 – 3.63	19	0.597	0.515 – 0.676	19	0.20	0.19 – 0.21	19	<0.0001	<0.0001 – 0.0001	19	*Not tested*		
S27/0607	760	489 – 834	19	0.002	<0.002 – 0.02	19	0.003	<0.002 – 0.029	18	*10.2*	7.46 – 11.6	19	16.0	10.8 – 18.0	19	1.400	0.920 – 1.580	19	0.30	0.28 – 0.39	19	<0.0001	<0.0001 – 0.0004	19	*Not tested*		
S27/0614	270	230 – 284	21	0.003	0.001 – 0.008	21	0.002	<0.002 – 0.020	21	0.78	0.64 – 0.93	21	4.40	3.10 – 5.50	21	0.697	0.470 – 0.848	21	0.17	0.14 – 0.22	21	<0.0001	<0.0001 – 0.0003	21	*Not tested*		
S27/0615	215	187 – 240	21	0.003	0.001 – 0.011	21	0.003	<0.002 – 0.043	21	0.52	0.41 – 1.63	21	6.90	4.25 – 8.90	21	0.519	0.307 – 0.630	21	0.22	0.19 – 0.29	21	<0.0001	<0.0001 – 0.0002	21	*Not tested*		
S27/0681	255	237 – 281	19	<0.002	<0.002	19	0.212	0.072 – 0.809	19	<0.01	<0.01 – 0.02	19	<0.02	<0.02 – 0.02	19	0.001	<0.0005 – 0.003	19	0.11	0.09 – 0.15	19	0.0001	<0.0001 – 0.0002	19	<1	<1 – 4	19
T26/0003	61.5	46.9 – 89.1	20	<0.002	<0.002 – 0.003	20	*1.87*	0.384 – 5.13	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02 – 0.08	20	0.001	<0.0005 – 0.003	20	0.06	0.04 – 0.08	20	0.0002	0.0001 – 0.0004	20	<1	<1	20
T26/0087	83.0	74.9 – 103	20	<0.002	<0.002	20	0.980	0.250 – 2.87	20	<0.01	<0.01 – 0.02	20	0.05	0.01 – 0.12	20	0.004	0.001 – 0.017	20	0.06	0.04 – 0.09	20	0.0001	<0.0001 – 0.0005	20	*Not tested*		
T26/0099	110	100 – 149	20	<0.002	<0.002	20	*5.60*	4.29 – 7.18	20	<0.01	<0.01 – 0.02	20	<0.02	<0.02	20	0.002	0.001 – 0.003	20	0.09	0.06 – 0.10	20	<0.0001	<0.0001 – 0.0001	20	<1	<1	20
T26/0206	100	92 – 118	20	0.017	0.013 – 0.02	20	1.52	1.29 – 1.77	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02	20	0.041	0.036 – 0.046	20	0.08	0.06 – 0.10	20	<0.0001	<0.0001	20	<1	<1	20
T26/0259	58.5	39.8 – 90.0	20	<0.002	<0.002	20	1.03	0.415 – 3.71	20	<0.01	<0.01 – 0.07	20	<0.02	<0.02	20	<0.0005	<0.0005 – 0.001	20	0.04	0.02 – 0.06	20	0.0002	<0.0001 – 0.0004	20	<1	<1	20
T26/0332	150	130 – 163	20	0.006	0.003 – 0.007	20	0.745	0.526 – 1.17	20	0.01	<0.01 – 0.03	20	<0.02	<0.02	20	1.370	1.200 – 1.405	20	0.23	0.20 – 0.25	20	<0.0001	<0.0001 – 0.0009	20	<1	<1	19
T26/0413	110	100 – 130	20	<0.002	<0.002	20	<0.002	<0.002 – 0.003	20	0.05	0.04 – 0.11	20	0.30	0.17 – 0.52	20	0.145	0.097 – 0.211	20	0.09	0.06 – 0.11	20	<0.0001	<0.0001 – 0.0003	20	*Not tested*		
T26/0430	69.0	62.5 – 94.4	20	<0.002	<0.002	20	1.49	0.825 – 4.24	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02	20	<0.0005	<0.0005 – 0.001	20	0.05	0.03 – 0.07	20	<0.0001	<0.0001	20	<1	<1 – 20	20
T26/0489	210	201 – 230	20	<0.002	<0.002 – 0.003	20	*11.0*	9.79 – 12.0	20	<0.01	<0.01 – 0.01	20	<0.02	<0.02 – 0.06	20	0.001	<0.0005 – 0.002	20	0.06	0.05 – 0.11	20	0.0002	<0.0001 – 0.0009	20	*Not tested*		
T26/0538	240	218 – 282	20	<0.002	<0.002 – 0.009	20	*10.1*	8.69 – 12.5	20	<0.01	<0.01 – 0.03	20	<0.02	<0.02 – 0.07	20	0.001	0.001 – 0.069	20	0.11	0.09 – 0.13	20	<0.0001	<0.0001 – 0.0001	20	<1	<1	20
Riversdale																											
T27/0063	350	314 – 421	9	<0.002	<0.002	19	*2.33*	0.857 – 7.85	19	<0.01	<0.01 – 0.02	19	<0.02	<0.02	9	<0.0005	<0.0005 – 0.002	9	0.06	0.04 – 0.09	9	<0.0001	<0.0001 – 0.0001	9	<1	<1 – 10	19

The influence of salinity and coastal environmental conditions can account for the higher TDS concentrations recorded at some bores located on the Kapiti Coast and at Riversdale on the eastern Wairarapa coast. In contrast, high TDS concentrations recorded in bores located in confined and semi-confined aquifers on the Kapiti Coast and in the Wairarapa Valley are largely a function of aquifer confinement and reduced groundwater conditions (see Section 4.4).

(b) Nitrite nitrogen

Median nitrite concentrations ranged from <0.002 mg/L to 0.017 mg/L (Table 4.3). No median concentrations were above the DWSNZ (2005) MAV of 0.06 mg/L (or the ANZECC (2000) stockwater TV) although concentrations in some individual samples collected from bores S27/0433 and T26/0538 in the Wairarapa Valley exceeded the DWSNZ (2005); maximum recorded concentrations in these bores were 0.1 mg/L and 0.12 mg/L respectively. Neither bore is used as a drinking water supply.

Nitrite concentrations were recorded in bores located in all types of aquifer confinement. However, nitrite concentrations were highest in bores assigned to B group sub-clusters located in confined aquifers in the Wairarapa Valley (Figure 4.7). This may reflect the oxygen-poor environments associated with these aquifers.

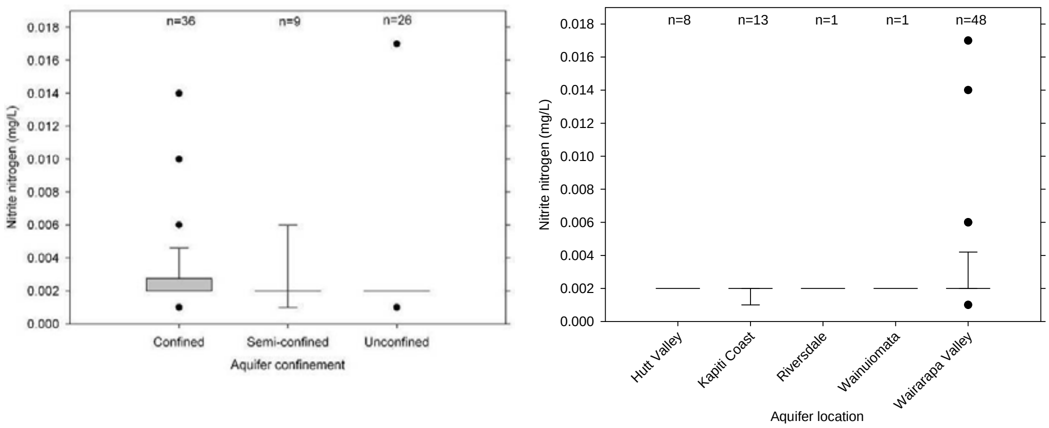


Figure 4.7: Box plots of median nitrite nitrogen concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped according to both aquifer confinement (left) and aquifer location (right)

(c) Nitrate nitrogen

Median nitrate concentrations ranged from <0.002 mg/L to 11 mg/L (Table 4.3) and complied with the DWSNZ (2005) MAV of 11.3 mg/L. However, nitrate concentrations in individual samples from bores S25/5322 (27 m deep), S26/0223 (9.92 m), T26/0489 (54 m) and T26/0538 (9 m) were above the DWSNZ (2005) MAV, with maximum concentrations of 11.4 mg/L (February 2007), 12 mg/L (March 2009), 12 mg/L (September 2008) and 16 mg/L (September 2008), respectively. Three of these four bores are assigned to the A2a sub-cluster, The fourth bore (S26/0223), located in the upper Wairarapa Valley, was the only one of these bores used for regular potable supply and was assigned to sub-cluster A1b. (Bore T26/0489 is used for potable supply when rainwater supply is low). Overall, median nitrate concentrations were elevated (>3 mg/L) in nine bores and highly elevated (>7 mg/L) in a further six bores; all of these bores are assigned to the A1b and A2a sub-clusters and located in area of pastoral land use, suggesting that groundwater in these bores is affected by human activity.

Median nitrate concentrations varied with aquifer confinement and location (Figure 4.8). A statistically significant difference (Kruskal-Wallis test, $p<0.0001$) was observed between median concentrations in confined, semi-confined and unconfined aquifers. In the Wairarapa Valley, median nitrate concentrations tended to be highest in the shallow unconfined aquifers (Figure 4.9)[16] where the influence of land use and interaction with surface water is greatest. In some (5 of 17) of these bores, nitrate concentrations exhibited strong seasonality (Kruskal-Wallis test, $p<0.0044$–0.0276), with higher concentrations generally recorded in the winter when rainfall is greater, the soils are more saturated, and groundwater levels are higher (Figure 4.10).

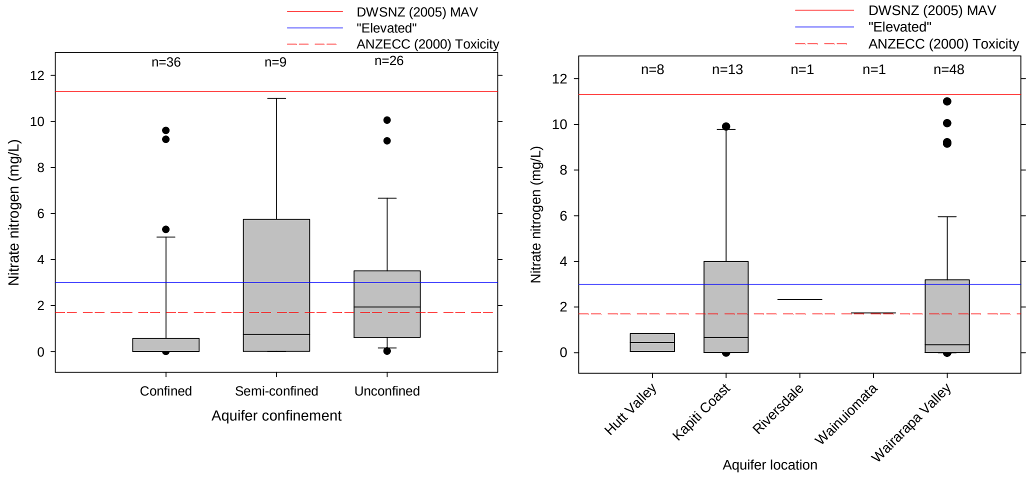


Figure 4.8: Box plots of median nitrate nitrogen concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped by both aquifer confinement (left) and aquifer location (right)

In terms of potential aquatic toxicity, 23 bores recorded median nitrate concentrations (medians range 1.74–11 mg/L) above the 1.7 mg/L threshold recommended by Hickey and Martin (2009). Of these, 17 are located in unconfined to semi-confined aquifers where there is an increased likelihood of discharge to surface water.

[16] A Pairwise Multiple Comparison test using Dunn's Method indicated there was a statistically significant difference ($p<0.05$) between the median nitrate concentrations recorded in the unconfined aquifers versus those recorded in confined aquifers.

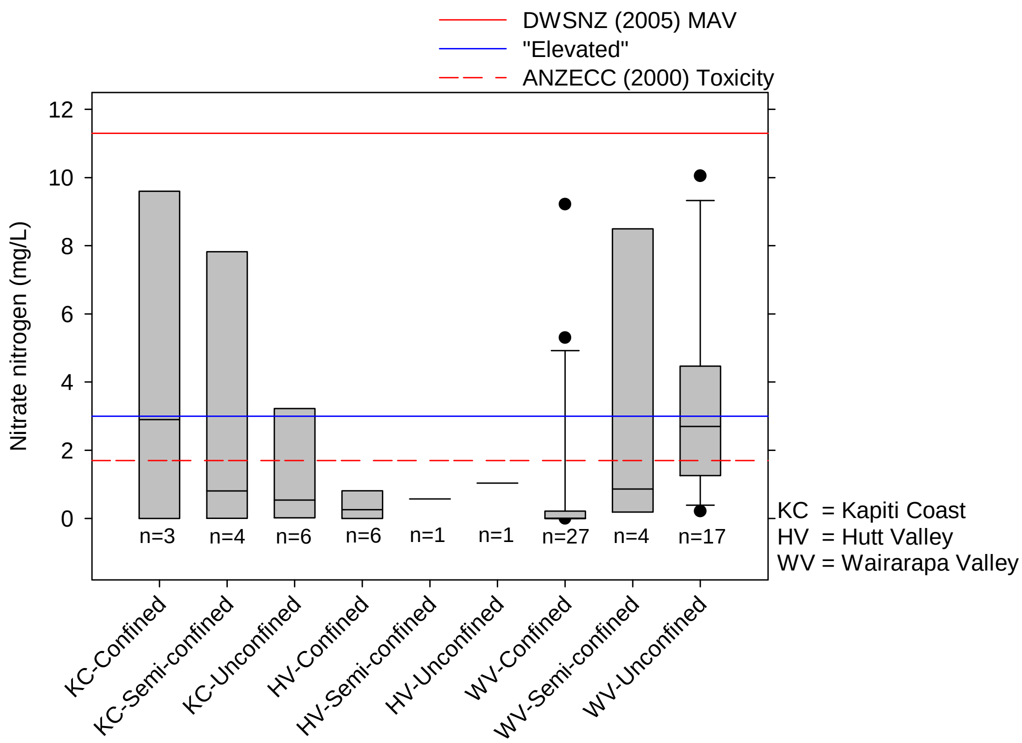


Figure 4.9: Box plots of median nitrate nitrogen concentrations in 69 GQSoE groundwater bores (Wainuiomata and Riversdale bores excluded) sampled quarterly between August 2005 and July 2010, grouped by both location and aquifer confinement

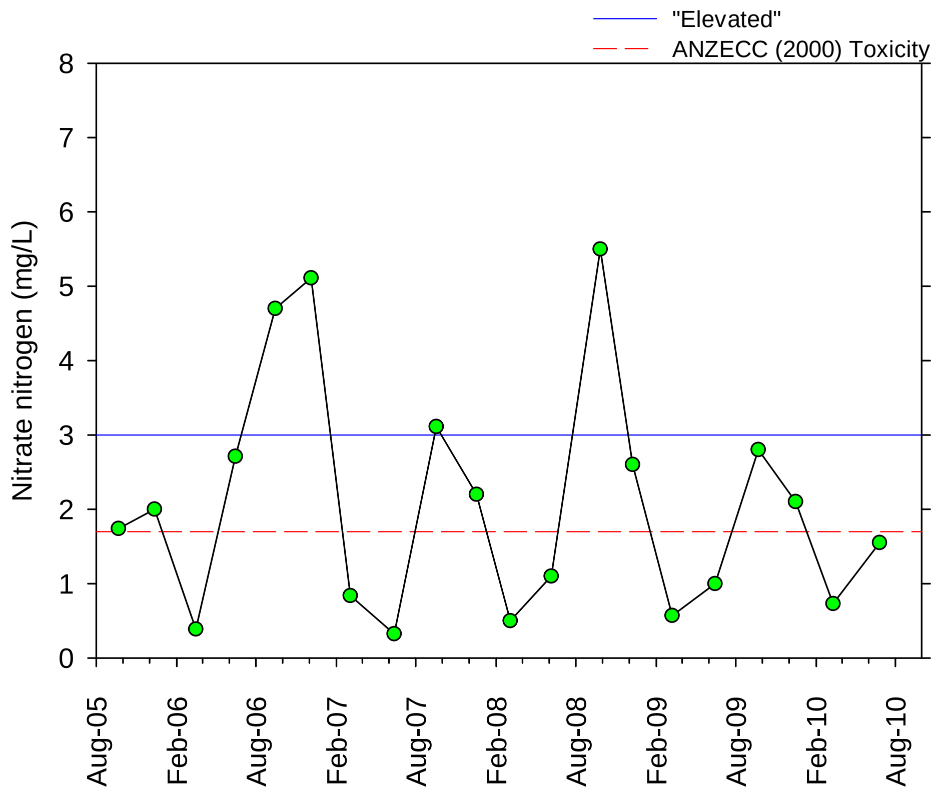


Figure 4.10: Nitrate nitrogen (nitrate) concentrations recorded in bore T26/0003 (5.5 m deep) in the Upper Opaki groundwater zone near Masterton, based on quarterly sampling over August 2005 to July 2010. A Kruskal-Wallis test confirmed significant seasonality in nitrate concentrations (four seasons, $p<0.0044$).

(d) Ammoniacal nitrogen

Median ammonia concentrations ranged from <0.002 mg/L to 10.2 mg/L (Table 4.3), with five bores recording median values above the DWSNZ (2005) GV of 1.5 mg/L: S27/0495, S27/0602, S27/0433, S27/0435 and S27/0607. None of these bores are used for drinking water. Median ammonia concentrations also exceeded the ANZECC (2000) trigger value for aquatic toxicity of 0.9 mg/L[17] in seven bores although all of these bores are located in confined aquifers in the lower Wairarapa Valley where the risk of groundwater discharge to surface water is minimal.

Maximum ammonia concentrations of 8.55 mg/L, 8.7 mg/L and 12 mg/L were recorded on individual sampling occasions in bores S27/0433, S27/0435 and S27/0607, respectively. All three of these bores are located in deep confined aquifers in the lower Wairarapa Valley and are assigned to the B2a and B2b sub-clusters. Bores in these aquifers tended to record the highest median ammonia concentrations (Figure 4.11); this is a reflection of the slow moving nature and low oxygen content of the water in these aquifers (conditions which favour the formation of ammonia).

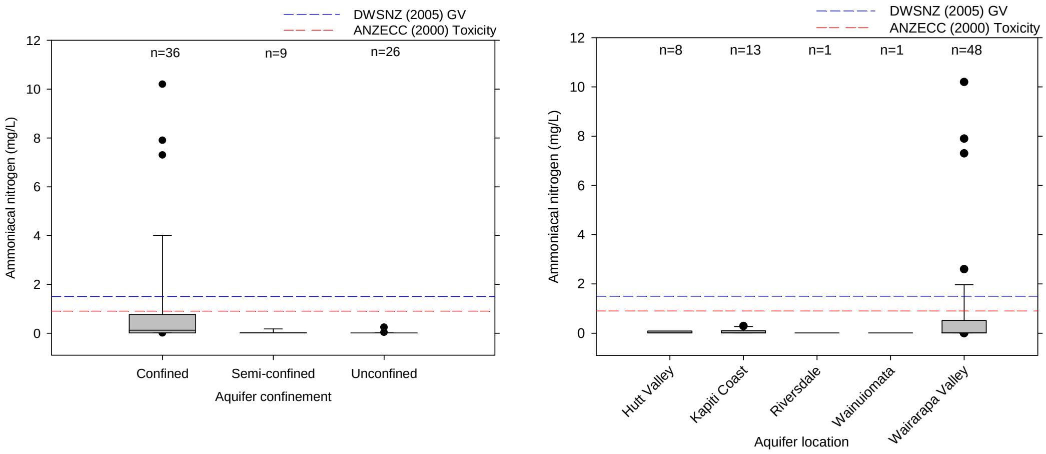


Figure 4.11: Box plots of median ammoniacal nitrogen concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped by both aquifer confinement (left) and aquifer location (right)

A plot of median nitrate concentrations against median ammonia concentrations for all 71 GQSoE bores (Figure 4.12) suggests that when ammonia concentrations are relatively high the associated concentrations are low and vice versa. This is consistent with the findings of PCA (Section 4.1.2) which showed nitrate is inversely correlated to ammonia. This is to be expected given the formation of ammonia in oxygen-poor environments such as those which tend to exist in confined aquifers (Figure 4.12). Bores S25/5256, S26/0824 and S27/0571 represent exceptions; while Greater Wellington's records indicate that these bores are located in confined aquifers, the presence of median concentrations of nitrate in the 'highly elevated' range suggests that they may in fact be semi-confined (ie, the confinement status of these bores should be reviewed).

[17] Applicable at pH 8.0 – refer to Table 4.2.

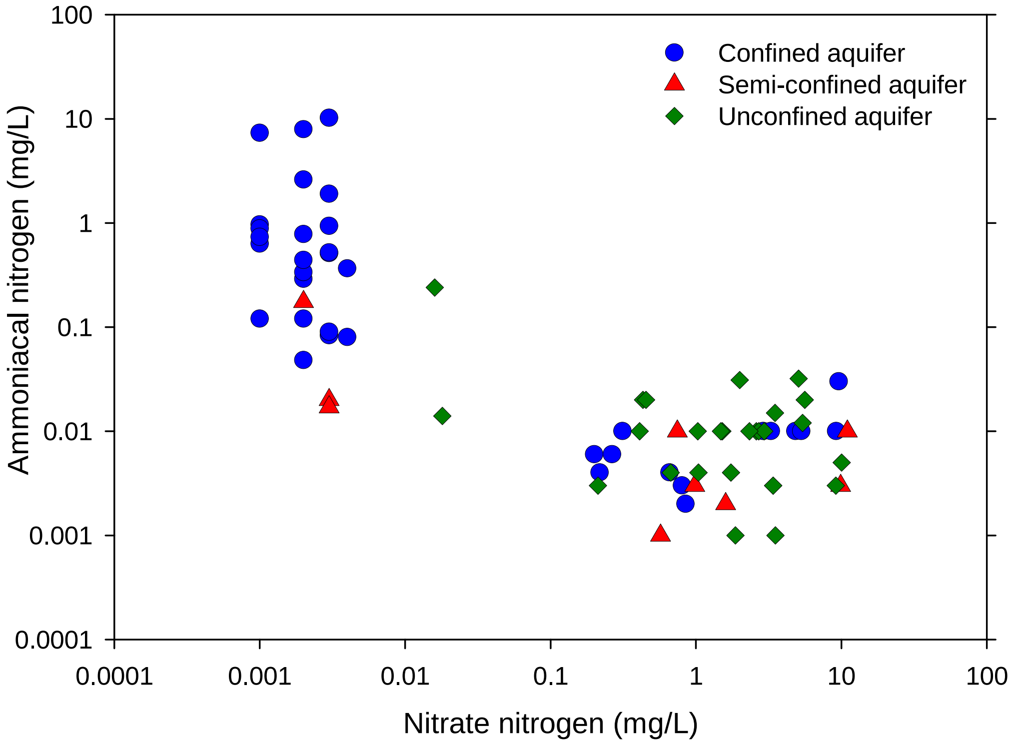


Figure 4.12: Median ammoniacal nitrogen and nitrate nitrogen concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010. Note the logarithmic scales on both axes.

Bore S25/5256 is located in an area on the Kapiti Coast used for horticulture while bore S27/0571 is located on a golf course in Martinborough. Anecdotal evidence suggests elevated nitrate concentrations recorded in these bores may be due to intensive applications of nitrogen-based fertiliser (assisted by aquifer conditions that still favour oxidation over reduction). Bore S26/0824 is located on the outskirts of Carterton township; it is possible that elevated concentrations of nitrate in this bore are due to migration of nitrate-rich groundwater from a recharge area upgradient of the bore where land use is more intensive.

(e) Iron and manganese

Iron and manganese are considered together since elevated soluble concentrations of both tend to coincide in reducing or oxygen-poor environments[18].

Median iron concentrations ranged from <0.02 mg/L to 10.2 mg/L (Table 4.3) and exceeded the DWSNZ (2005) GV of 0.2 mg/L in 25 bores, most of which were assigned to B group sub-clusters and are not used for potable supply (only bores S27/0442, S27/0588 and T26/0413 are used for potable supply). A maximum iron concentration of 18.01 mg/L was recorded on one sampling occasion in bore S27/0607 located in the confined aquifer of the lower Wairarapa Valley. This bore also recorded the second highest median

[18] Generally, there is no statistical correlation between iron and manganese despite both variables usually being present together in high concentrations. This is probably because manganese dissolves out first before iron during rock-water interaction in reducing conditions. Iron is also more abundant than manganese in most rock types (Rosen 2001).

concentration of manganese (1.4 mg/L). As noted in Table 4.2, ANZECC (2000) does not specify an aquatic toxicity threshold for iron.

Median manganese concentrations ranged from <0.0005 mg/L to 1.6 mg/L (Table 4.3), with 20 bores (all assigned to B group sub-clusters) recording medians above the DWSNZ (2005) MAV of 0.4 mg/L. A further 12 bores recorded median values above the DWSNZ (2005) GV of 0.04 mg/L (Table 4.3). A maximum manganese concentration of 1.94 mg/L was recorded on one sampling occasion in bore S27/0433 (marginally above the ANZECC (2000) toxicity TV of 1.9 mg/L) – this bore also had the second highest median iron concentration (12.6 mg/L). None of the 20 bores with median values above the MAV are used for drinking water purposes.

Figure 4.13 indicates that iron and manganese concentrations are greater in the semi-confined and confined aquifers on the Kapiti Coast and the Wairarapa Valley, and in bores assigned to the B group sub-clusters. The greatest iron and manganese concentrations were seen in the deep confined bores of the Wairarapa Valley. This is to be expected; iron is soluble in oxygen-poor conditions, which are typical in deeper semi-confined to confined aquifers. A high proportion of bores with the greatest manganese concentrations also had the greatest iron concentrations, suggesting that the elevated manganese and iron concentration are due to natural processes (eg, rock-water interaction) rather that human impact.

(f) Fluoride

Median fluoride concentrations ranged from <0.05 mg/L to 0.54 mg/L (Table 4.3) and none exceeded the DWSNZ (2005) MAV of 1.5 mg/L or the ANZECC (2000) stockwater TV of 2 mg/L. However, a maximum fluoride concentration of 1.7 mg/L was recorded on one sampling occasion in bore S27/0568. This bore is not used as a drinking water supply.

Median fluoride concentrations were higher in the semi-confined and confined aquifer types than in the unconfined aquifers (Figure 4.14), as confirmed by a Kruskal-Wallis test ($p<0.0001$). However, there was no pattern between fluoride concentrations and hydrochemistry sub-cluster assignment.

(g) Lead

Median dissolved lead concentrations were one to two orders of magnitude below the DWSNZ (2005) MAV (0.01 mg/L) across all 71 GQSoE bores, ranging from <0.0001–0.001 mg/L (Table 4.3). Median lead concentrations were also below both the ANZECC (2000) stockwater and aquatic toxicity TVs (0.1 mg/L and 0.0034 mg/L, respectively). However, concentrations in water samples from bores S27/0396 and R27/1180 exceeded the ANZECC (2000) toxicity TV on several occasions (the maximum concentrations recorded in these bores were 0.006 mg/L and 0.004 mg/L, respectively). Neither bore is located in an area of surface water/groundwater interaction.

Overall, lead concentrations were generally low and not typical of any particular aquifer type, sub-cluster group or geographic location. This suggests there has been no serious lead contamination of groundwater that can be attributed to human activities (Figure 4.15).

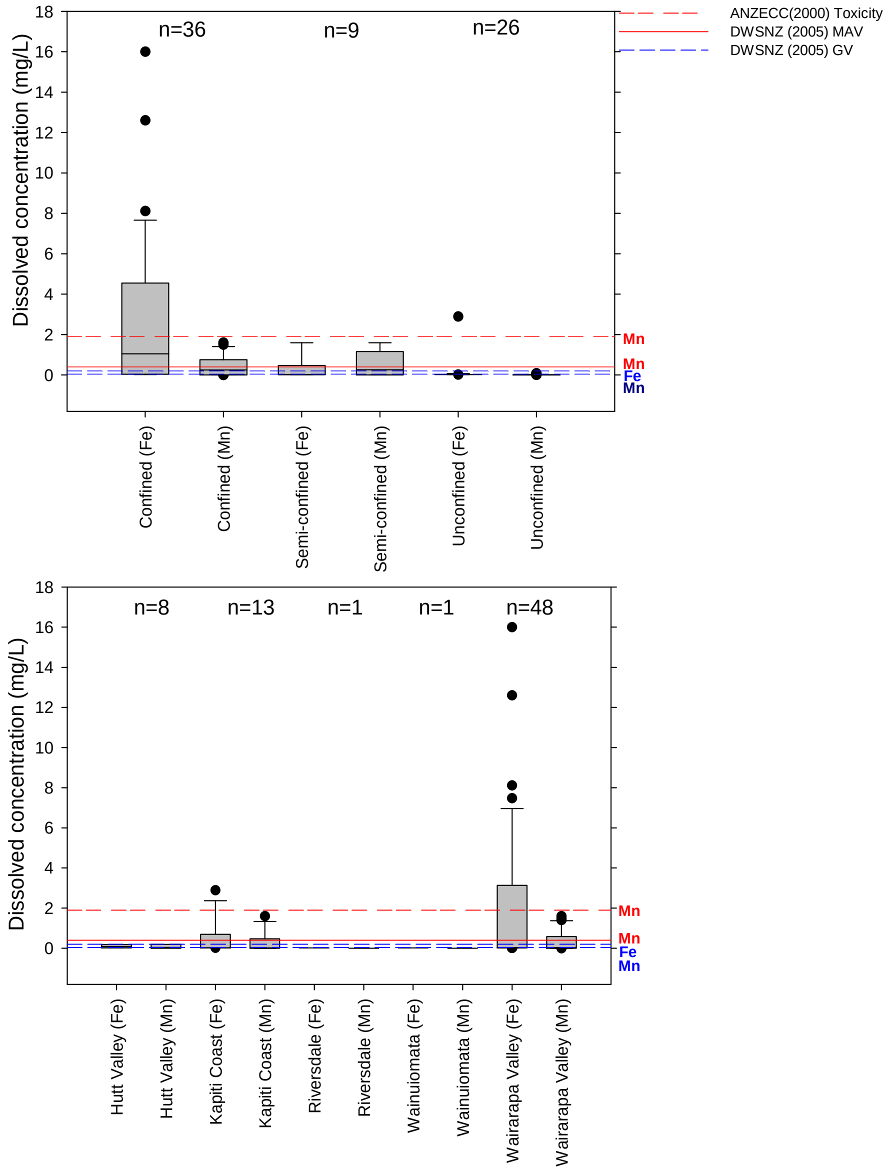


Figure 4.13: Median iron (Fe) and manganese (Mn) concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped by both aquifer confinement (top) and aquifer location (bottom)

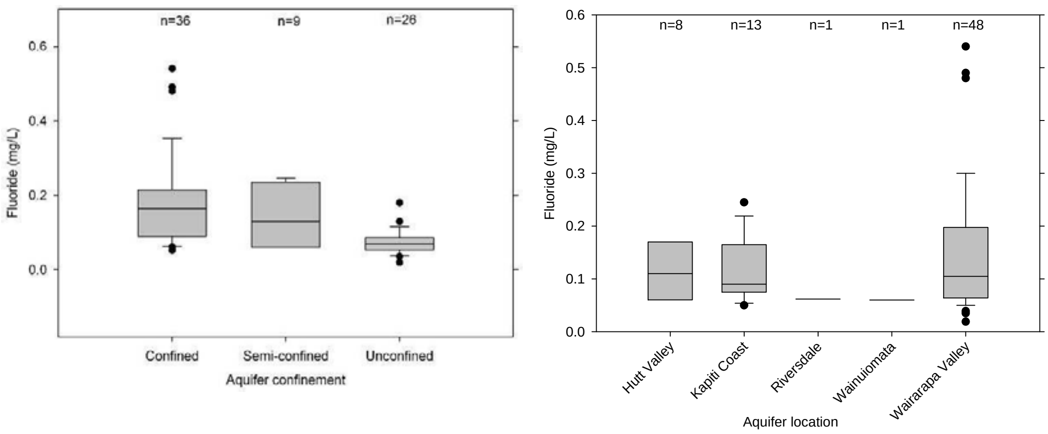


Figure 4.14: Box plots of median fluoride concentrations in GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped by both aquifer confinement (left) and aquifer location (right)

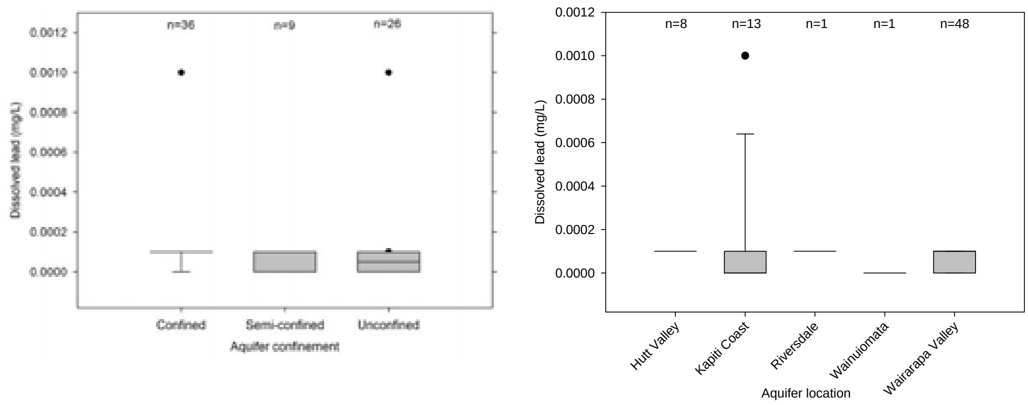


Figure 4.15: Box plots of median dissolved lead concentrations in 71 GQSoE bores sampled quarterly between August 2005 and July 2010, with bores grouped by both by aquifer confinement (left) and aquifer location (right)

(h) Escherichia coli

Median counts of *E. coli* bacteria ranged from <1 cfu/100mL to 37 cfu/100mL (Table 4.3). While only one bore (R25/5164) recorded a median value greater than the DWSNZ (2005) MAV (<1 cfu/100mL), 26 of the 44 bores (59%) in the GQSoE monitoring programme returned positive *E. coli* bacteria counts on one or more sampling occasions between July 2005 and July 2010. Six of these 25 bores are used as drinking water supplies; *E. coli* counts were generally <3 cfu/100mL, the exception being bore S27/0136 where *E. coli* counts exceeded 3 cfu/100ml on four occasions. Counts of *E. coli* bacteria counts exceeded the ANZECC (2000) stockwater TV (100 cfu/100mL) on one or more sampling occasions in three of the 44 bores.

A maximum *E. coli* count of 3,000 cfu/100mL was measured on one sampling occasion in bore R25/5164 at Te Horo Beach on the Kapiti Coast; this bore also recorded counts of 2,800 cfu/100mL and 800 cfu/100mL on two other sampling occasions. Te Horo Beach is a small settlement reliant on on-site wastewater treatment systems for effluent disposal. Previous studies involving dye tracer tests have confirmed that groundwater at Te Horo Beach is able to move from wastewater treatment systems to nearby bores relatively quickly (Hughes 1998).

Figure 4.16 suggests that *E. coli* bacteria contamination of groundwater can occur in most parts of the Wellington region. However, counts of *E. coli* above 100 cfu/100mL occurred most often on the Kapiti Coast and in the Wairarapa Valley and in bores assigned to the A group sub-clusters in the unconfined to semi-confined aquifers. While this may be a function of the majority of GQSoE bacteria sampling sites being located in these areas and aquifer types, the bores are also located in areas of intensive land use where the likelihood of contamination of shallow groundwater is high.

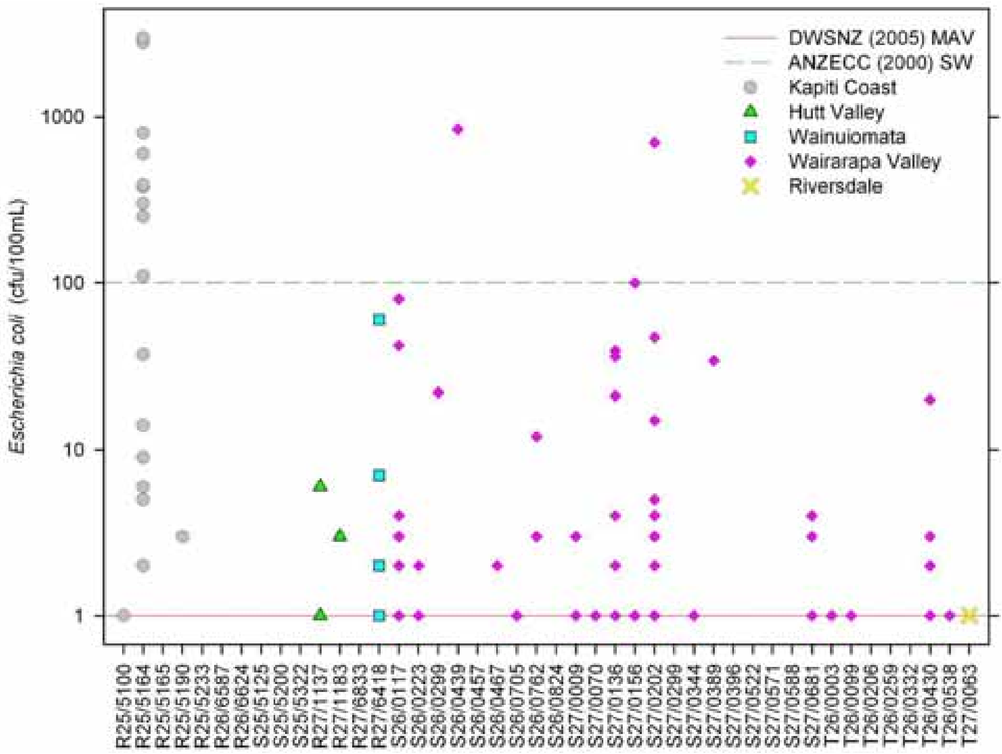


Figure 4.16: Positive *Escherichia coli* counts recorded on individual sampling occasions in groundwater samples collected from 71 GQSoE bores sampled quarterly between August 2005 and July 2010

4.2.3 Heavy metals, metalloids and pesticides

This section summarises information on heavy metals, metalloids and pesticide concentrations in groundwater collected between August 2005 and July 2010. None of these substances tend to be present in significant concentrations in groundwater in the Wellington region, hence testing for these variables is conducted infrequently compared with the quarterly testing for the suite of 30 variables included in the GQSoE monitoring programme.

(a) Heavy metals and metalloids

In addition to dissolved lead and zinc which are routinely analysed in Greater Wellington's GQSoE programme, in March 2009 GQSoE samples were tested for dissolved arsenic, cadmium, chromium, copper and nickel. These one-off tests were used to provide a more up-to-date picture of trace metal and metalloid concentrations in groundwater in the Wellington region.

Cadmium, chromium, copper, nickel, lead and zinc were detected in groundwater samples from some bores, but all concentrations were below DWSNZ (2005) MAV or guideline values. In contrast, arsenic was detected in water samples from 20 bores, with concentrations in three non-potable bores (S26/0568, S27/0435 and S27/0607, 38 to 44 m deep) in the Wairarapa Valley exceeding the DWSNZ (2005) MAV of 0.01 mg/L (Figure 4.17). In general, arsenic was detected in groundwater samples from bores assigned to B group sub-clusters that were greater than 10 m deep and located in Kapiti and the Wairarapa Valley. Low concentrations of arsenic were also detected in shallow coastal bores at Te Horo Beach and Riversdale.

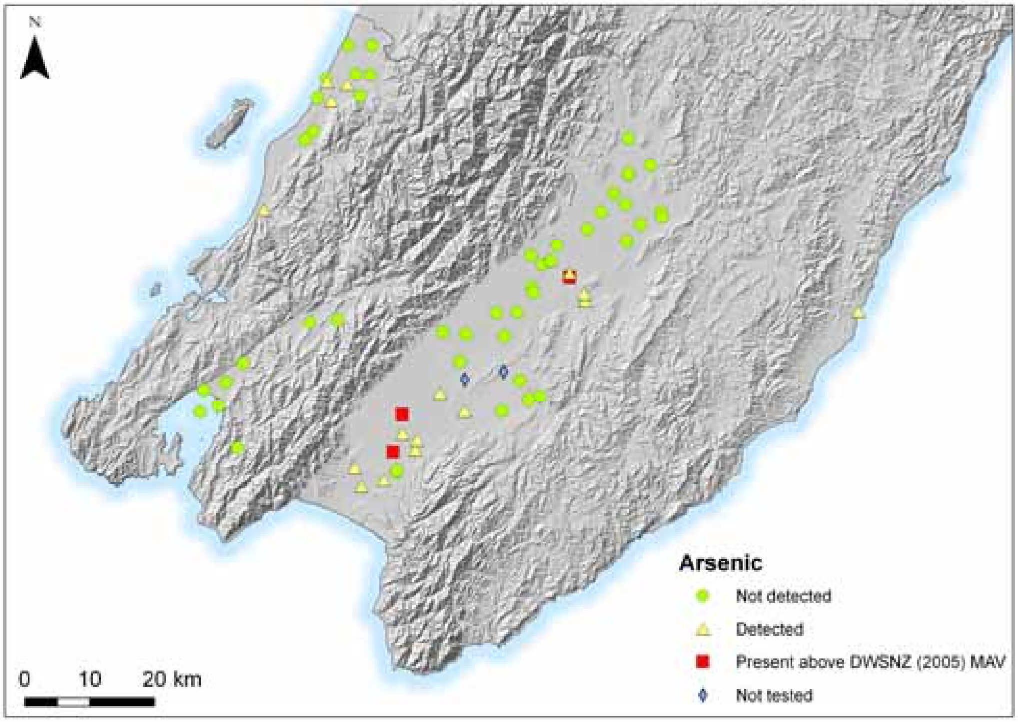


Figure 4.17: Dissolved arsenic concentrations recorded in routine groundwater samples from 71 GQSoE bores in March 2009

Figure 4.18 indicates that the highest concentrations of arsenic were recorded in semi-confined to confined bores that also recorded the highest iron concentrations. The correlation between iron and arsenic (r_s=0.658, p<0.0001, Spearman Rank Order test) suggests dissolved iron concentrations could be used to indicate where there is a potential risk of elevated concentrations arsenic in groundwater.

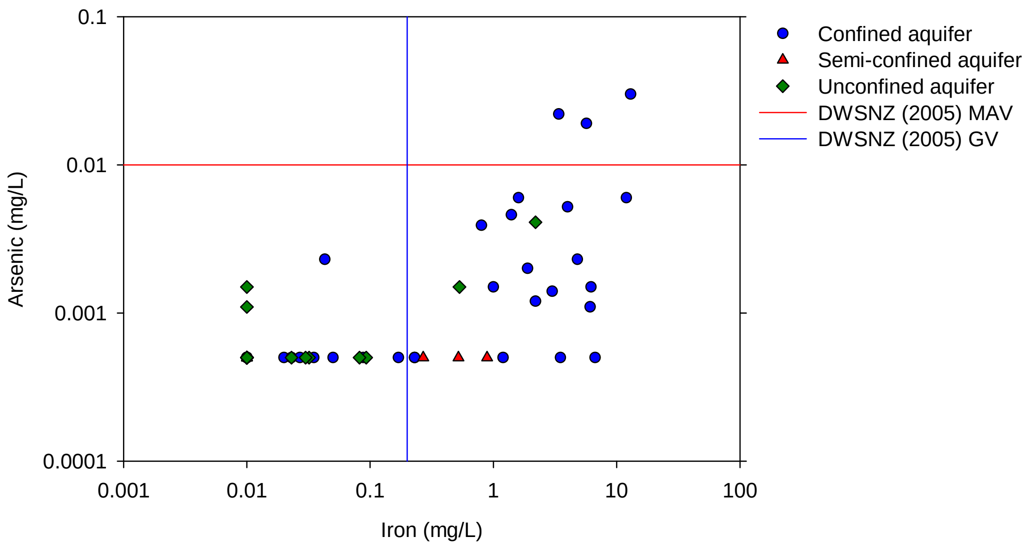


Figure 4.18: The relationship between dissolved arsenic and iron concentrations in 71 GQSoE bores sampled in March 2009, grouped according to aquifer confinement. Note the logarithmic scale on both axes.

Given that the geology of the Wellington region consists of mainly greywacke and marine-derived sediments and both iron and arsenic are soluble in oxygen-poor conditions, it is likely that arsenic occurs naturally in the groundwater (especially in the oxygen-poor aquifer systems of the lower Wairarapa Valley). Pesticides, timber treatment sites and old sheep and cattle dip sites can contribute to anthropogenic sources of arsenic in groundwater (Davies 2001; Rosen 2001). However, these do not appear to be significant sources of arsenic in groundwater in the Wellington region.

(b) Pesticides

Greater Wellington samples selected groundwater bores located in areas of horticulture or industry (see Appendix 1) at four-yearly intervals as part of Environmental Science and Research's (ESR) national pesticide monitoring programme. Pesticides detected in the two most recent pesticide surveys – conducted in 2006 (17 bores) and 2010 (13 bores) – are outlined in Table 4.4.

Pesticides were detected in two bores located in unconfined gravel aquifers, one in an area of intensive horticulture and agriculture on the Kapiti Coast, and one located at a golf course in Wainuiomata. Although all measured concentrations were below their respective MAVs, pesticides have been detected in both bores previously (four of six sampling occasions for bore S25/5125). This suggests that pesticides and herbicides are still being used at these sites or groundwater movement is slow.

Table 4.4: Pesticides and herbicides detected in selected GQSoE bores sampled in 2006 and 2010 as part of ESR's national surveys of pesticides in groundwater

Bore	Depth (m)	Location	Land use	Pesticides detected	
				2006	2010
S25/5125 Bettys	10	Otaki	Horticulture	Norflurazon 0.000096 mg/L (MAV 0.05* mg/L)	Norflurazon 0.00004 mg/L
R27/6418 Wainuiomata GC	8	Wainuiomata	Golf course	Terbuthylazine 0.00012 mg/L (MAV 0.008 mg/L)	Terbuthylazine 0.000059

*Australian Drinking Water Guidelines (Australian Government 1996).

4.3 Groundwater quality index

In this section the overall quality of groundwater in the Wellington region is summarised by assigning a groundwater quality 'class' to each GQSoE bore using the methodology defined in the Canadian Water Quality Index (CCME 2001). Indices are increasingly being used as a means to summarise complex water quality data and the Canadian WQI is one that has already been trialled in several regions (eg, Auckland and Southland); more recently, this index has been recommended for further investigation in relation to national reporting of fresh water quality (Hudson et al. 2011).

Two types of WQI are presented in this section, one to summarise overall groundwater quality for potable use and one to summarise the potential for toxicity-related impacts of groundwater discharge to aquatic ecosystems. The water quality variables and thresholds utilised in each index are outlined in Section 4.3.1 along with a brief overview of the calculation of each WQI.

4.3.1 WQI variables, thresholds and calculation

The Canadian WQI, on which the indices in this section have been based, is based on three elements:

- *Scope*: the number of variables that do not meet the assigned compliance thresholds (known as the *objectives*) on at least one sampling occasion.
- *Frequency*: the frequency with which individual sample results fail to meet the assigned compliance thresholds.
- *Magnitude*: the amount by which individual sample results fail to meet the assigned compliance thresholds.

The three elements are combined to produce a single WQI value between 0 and 100 where the higher the value, the better the water quality (see Appendix 5 for calculation details). Once the WQI value has been determined, water quality is ranked by assigning it to one of the four categories outlined in Table 4.5. CCME (2001) note that the assignment of WQI values to these categories is somewhat subjective; the categories presented in Table 4.5 have been drawn from Auckland Regional Council (ARC 2010) who also evaluated groundwater quality for potable use and aquatic ecosystem purposes (but using a different suite of variables).

Table 4.5: Class thresholds in the two water quality indices used to assess the suitability of groundwater for potable drinking water and aquatic ecosystems purposes

(Source ARC 2010)

Class	Drinking WQI	Aquatic ecosystems WQI
Excellent	>90	>90
Good	70–90	75–90
Fair	50–70	60–75
Poor	<50	<60

Thirteen water quality variables were selected for inclusion in the Drinking WQI (Table 4.6). Most of these variables align with those used by ARC (2010), with the compliance thresholds drawn from the DWSNZ (2005); these include seven variables which have maximum acceptable values (MAV) for inorganic determinands of health significance, and six variables which have guideline values (GV) for aesthetic determinands. For ease of calculation, all variables were given equal weighting in the WQI; in practice, variables that exceed an MAV should probably carry a higher weighting to reflect their greater importance from a human health perspective.

The aquatic ecosystems WQI is based on key nutrients and trace elements that have at times been present at elevated concentrations in some GQSoE samples (Table 4.6). The compliance thresholds have largely been taken from the ANZECC (2000) freshwater toxicity trigger values (95% species protection level). Dissolved reactive phosphorus (DRP), although not a toxicant, was initially included in the WQI since it is a key soluble nutrient that has the potential to contribute to nuisance plant growth in surface water ecosystems. However, the only available ANZECC (2000) trigger value (0.010 mg/L for lowland streams) was considered overly conservative and would have severely biased WQI calculations (almost all of the 71 bores recorded a DRP concentration above 0.010 mg/L on one or more sampling occasions over the reporting period).

Table 4.6: Groundwater variables and guideline thresholds used in the Drinking WQI and the Aquatic Ecosystems WQI

Variable	Drinking WQI[1] DWSNZ (2005) (mg/L)	Aquatic Ecosystems WQI ANZECC (2000) toxicity TV (mg/L)
Dissolved boron	<1.4	
Fluoride	<1.5	
Dissolved lead	<0.01	0.0034
Dissolved manganese	<0.4	1.94
Nitrate nitrogen	<11.3	1.7
Nitrite nitrogen	<0.06	
E. coli	<1	
Chloride	<250	
Total hardness	<200	
Dissolved iron	<0.2	
pH (Lab)	7.0–8.5	
Dissolved sodium	<200	
Sulphate	<250	
Total dissolved solids	<1,000	
Dissolved zinc	<1.5	0.008
Ammoniacal nitrogen	<1.5	0.9

[1] DWZNZ (2005) MAVs denoted by grey shading, GVs are un-shaded.

Note that:

- The Drinking WQI is being applied to natural groundwater – poor quality water in some bores could be brought up to potable supply standards through appropriate treatment;

- For simplicity, the thresholds for the Aquatic Ecosystems WQI have been set on the assumption that groundwater makes up the entire surface water flow – as noted in Section 4.2.1(b), in reality, there will be some dilution of groundwater by surface water.

4.3.2 Drinking WQI

Based on quarterly monitoring results over the period August 2005 to July 2010, 34 of the 71 GQSoE bores had 'excellent' groundwater quality and were suitable for potable use (Figure 4.19). Bores in this 'excellent' class were located in a range of aquifer types (unconfined, semi-confined and confined) on the Kapiti Coast, Hutt Valley, upper Wairarapa Valley, and in the unconfined aquifers at Riversdale and Wainuiomata. Bores classified as 'good' (19 of 71 bores) were located in similar aquifer types and locations. In contrast, bores assigned to the 'poor' and 'fair' classes for drinking water purposes (3 and 15,

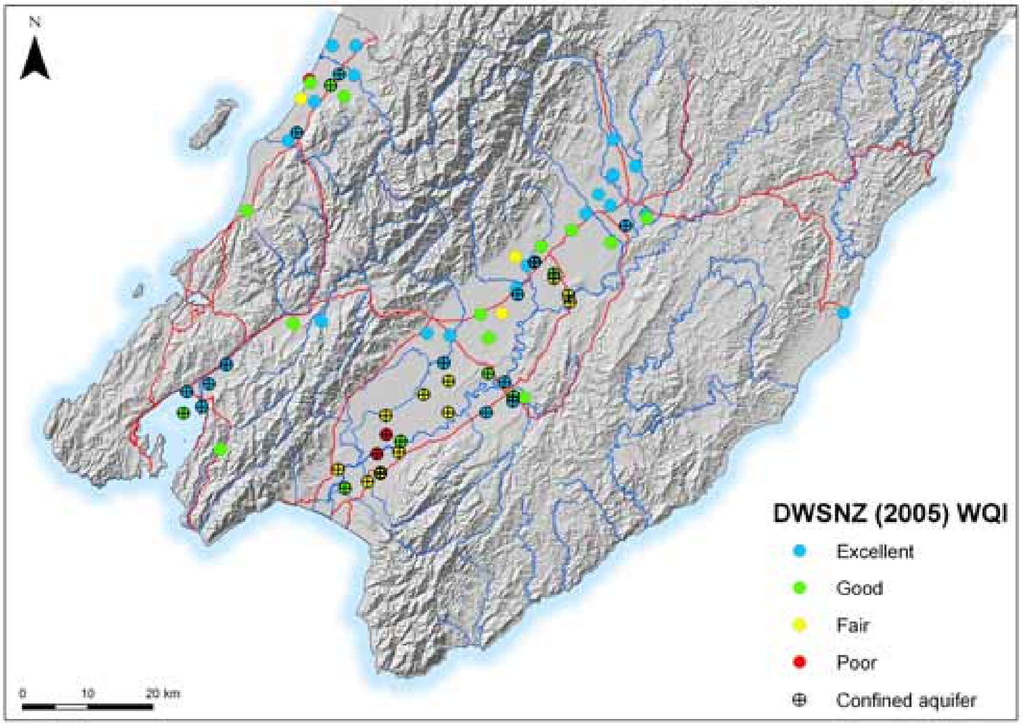


Figure 4.19: Summary of the suitability of groundwater for drinking water purposes at 71 GQSoE bores in the Wellington region, based on a WQI of 13 variables measured at quarterly intervals between August 2005 and July 2010

respectively) were mostly located in confined aquifers on the Kapiti Coast and the mid to lower Wairarapa Valley (just four bores assigned to these classes were located in unconfined or semi-confined aquifers).

The poorest water quality was assigned to bores R25/5164, S27/0433 and S27/0607. Bore R25/5164, located at Te Horo Beach on the Kapiti Coast, was not a suitable source of drinking water given that counts of *E. coli* were regularly detected above the DWSNZ (2005) MAV. Bores S27/0433 and S27/0607, located in confined aquifers in the lower Wairarapa Valley, were also unsuitable drinking water supplies (unless treated); concentrations of iron, manganese and ammoniacal nitrogen in these bores regularly exceeded their corresponding DWSNZ (2005) MAVs or GVs. While none of the bores classed as 'poor' are used for potable supply, one bore (S27/0588) classified as 'fair' is used for a public water supply by the South Wairarapa District Council. This bore failed to meet the dissolved iron GV on a regular basis.

When the Drinking WQI classifications for each GQSoE bore were grouped by HCA sub-cluster (Figure 4.20), groundwater considered as 'poor' or 'fair' for potable water supply was also considered naturally reduced hydrochemically. In contrast, the best drinking water is located in the A-group clusters that tend to be located in the unconfined to semi-confined aquifers. The 'good' to 'excellent' groundwater quality at these sites is likely to be maintained by regular recharge of aquifers due to high volumes of freshwater inputs from rainfall and river drainage.

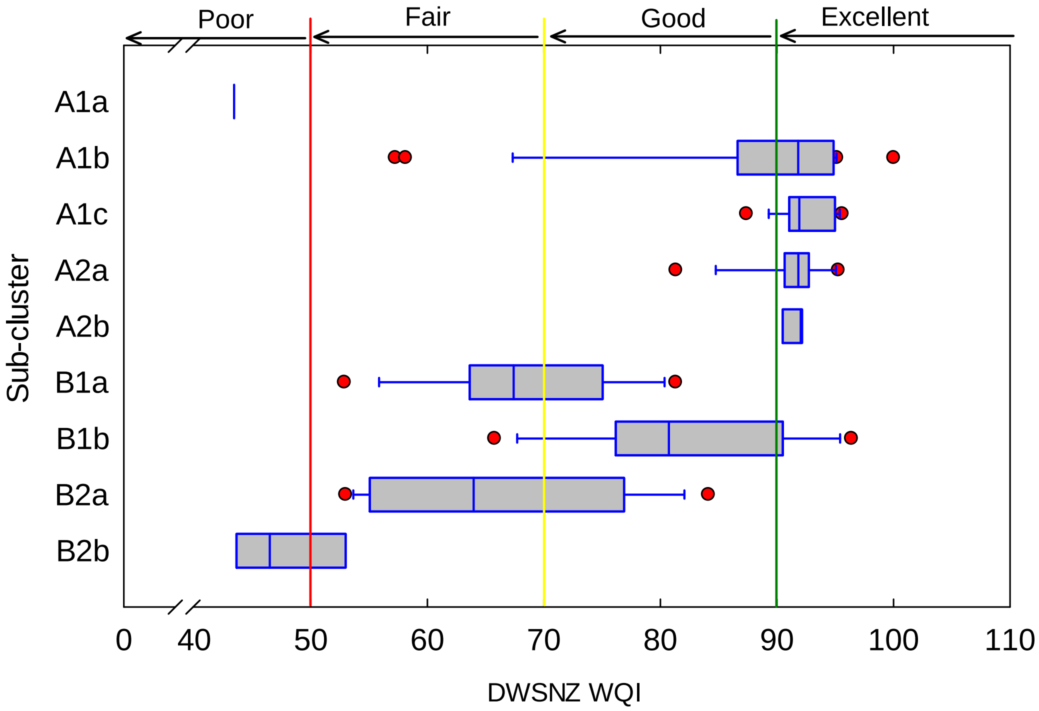


Figure 4.20: Box plot of Drinking WQI scores (based on GQSoE data collected between August 2005 and July 2010) grouped by sub-cluster category. The vertical coloured lines indicate the boundaries between WQI classes. Note the scale break on the *x*-axis.

4.3.3 Aquatic ecosystems WQI

Based on quarterly monitoring results over the period August 2005 to July 2010, five of the 71 GQSoE bores had a ranking of 'excellent' (Figure 4.21), indicating that the risk of toxicity to aquatic ecosystems was low. These bores are located in confined aquifers in the mid to lower Wairarapa Valley, with four of the five bores (bores S27/0594, S26/0762 S27/0588 and S26/0568) assigned to B-group hydrochemistry sub-clusters (Figure 4.21). The other bore, S26/0846, is assigned to hydrochemistry cluster A1c and was the only bore to receive an 'excellent' rating under both the Drinking WQI and the Aquatic Ecosystems WQI.

Groundwater quality in 30 bores was classified as 'good' under the Aquatic Ecosystems WQI. These bores were located throughout the region and across a range of types of aquifer confinement (confined, semi-confined and unconfined). Subsequently, HCA classifications spanned both A and B hydrochemistry cluster groups, in particular sub-clusters A1b, A1c, B1a, B1b and B2a (Figure 4.22). Bores classified as 'good' generally failed to meet ANZECC (2000) toxicity trigger values for dissolved zinc and, on occasion, ammoniacal nitrogen and nitrate nitrogen (nitrate).

Twenty-three bores were classified as having 'fair' water quality in terms of potential toxicity to aquatic ecosystems. Similar to the bores classified as 'good', these bores were located throughout the region and across a range of types of aquifer confinement. Bores in this category generally failed to meet ANZECC (2000) toxicity trigger values for nitrate, dissolved zinc and, on

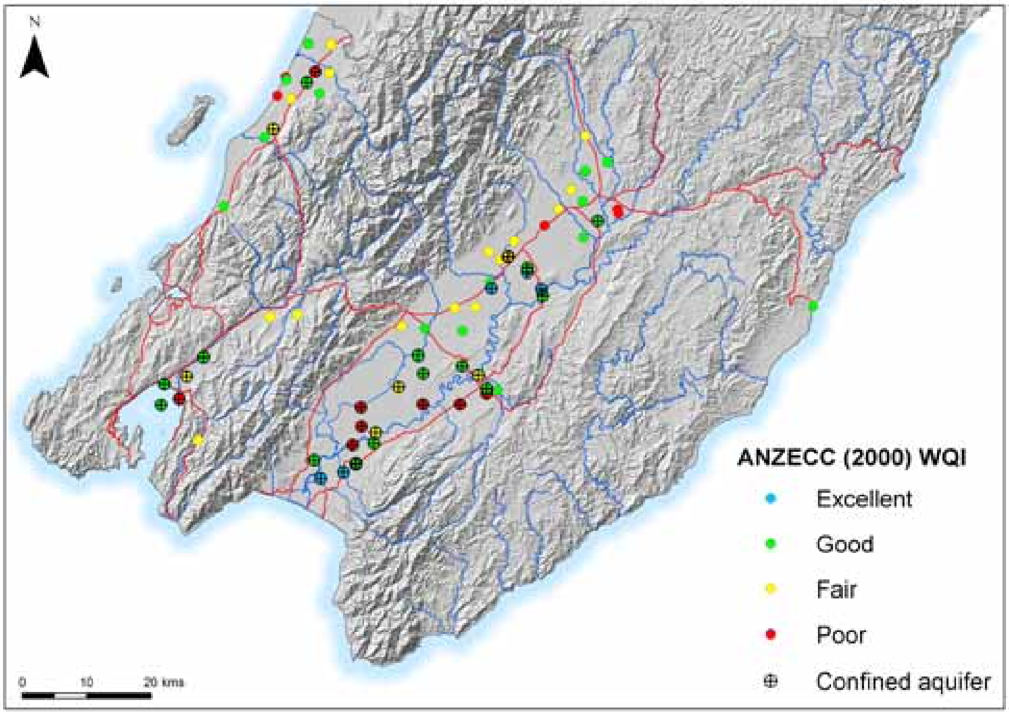


Figure 4.21: Summary of the suitability of groundwater for aquatic ecosystems at 71 GQSoE bores in the Wellington region, based on a WQI of six variables measured at quarterly intervals between August 2005 and July 2010

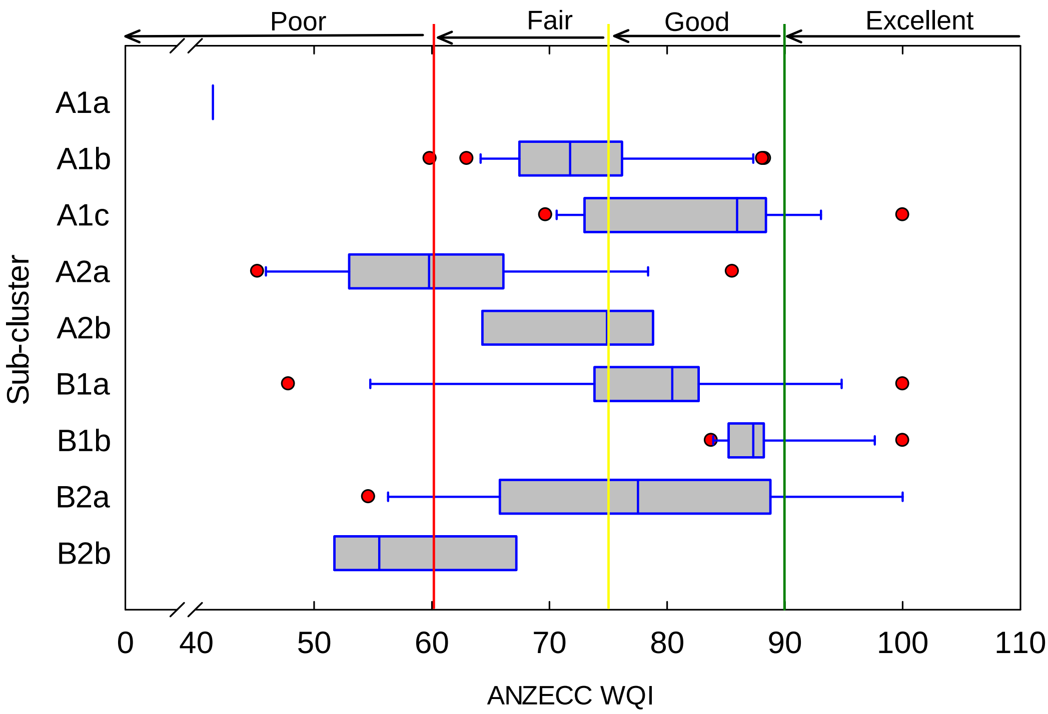


Figure 4.22: Box plot of aquatic ecosystems WQI scores (based on GQSoE data collected between August 2005 and July 2010) grouped by sub-cluster category. The vertical coloured lines indicate the boundaries between WQI classes. Note the scale break on the *x*-axis.

occasion, ammoniacal nitrogen. In terms of hydrochemistry, bores classified as 'fair' were largely assigned to the A group sub-clusters (19 of 23 bores), in particular sub-cluster A1b (Figure 4.22). As outlined earlier in Section 4.1.3, sub-cluster A1b bores tend to be located in unconfined or semi-confined aquifers in areas that are most utilised for intensive land use (upper to mid Wairarapa Valley and the Kapiti Coast).

Water quality in 13 bores was considered ‘poor’ under the Aquatic Ecosystems WQI. Eight of these bores are located in confined aquifers (mainly in the lower Wairarapa Valley) where discharge to surface water is considered minimal. Half of these bores were assigned to the B group sub-clusters (Figure 4.22) and generally failed to meet the ANZECC (2000) toxicity trigger value for ammoniacal nitrogen – a reflection of the naturally oxygen-poor aquifers in which they are located. In contrast, the other four bores were assigned to A2 group sub-clusters and generally failed to meet ANZECC (2000) toxicity trigger values for nitrate and zinc.[19]

The five remaining bores are located in unconfined to semi-confined aquifers on the Kapiti Coast and in the upper Wairarapa Valley, suggesting a potential hydraulic connection with surface water. These bores generally failed to meet ANZECC (2000) toxicity trigger values for nitrate and dissolved zinc. Based on a predominantly Cluster A hydrochemical classification (four of the five bores), groundwater quality in some of these bores is probably influenced by current or past human activity. For example:

- Bore R25/5164 is known to be affected by wastewater from septic tank disposal at Te Horo Beach settlement (Tidswell 2009) and is assigned to its own unique HCA sub-cluster (A1a).

- Bores T26/0489 and T26/0538 (sub-cluster A2a) are located in the same aquifer system in Te Ore Ore near Masterton and have elevated nitrate concentrations attributed to historical agricultural land use practices (van der Raaij 2000). Aquifers in the Te Ore Ore basin are thought to discharge by spring and groundwater seepage to the Poterau Stream (Butcher 2000; Gyopari & McAlister 2010a).

4.4 Synthesis

Groundwater chemistry in the Wellington region is strongly influenced by natural factors, principally redox potential and rock-water interaction, as well as human activity. The 71 GQSoE bores can be assigned to nine different hydrochemical sub-clusters (Figure 4.23); four of the five A group sub-clusters (ie, excluding A1a) are characterised by oxygen-rich groundwater sourced from rainfall recharge and/or river drainage from unweathered greywacke. Concentrations of nitrate and sulphate above background levels in these sub-clusters suggest human activity is influencing groundwater quality. The other four (B group) sub-clusters are typical of river drainage from weathered greywacke and/or generally confined groundwater influenced by oxygen-poor conditions and presumably a low rate of recharge or slow through flow.

[19] Hem (1985) describes zinc as having fairly common abundance in crustal rocks and it is soluble in most types of natural water.

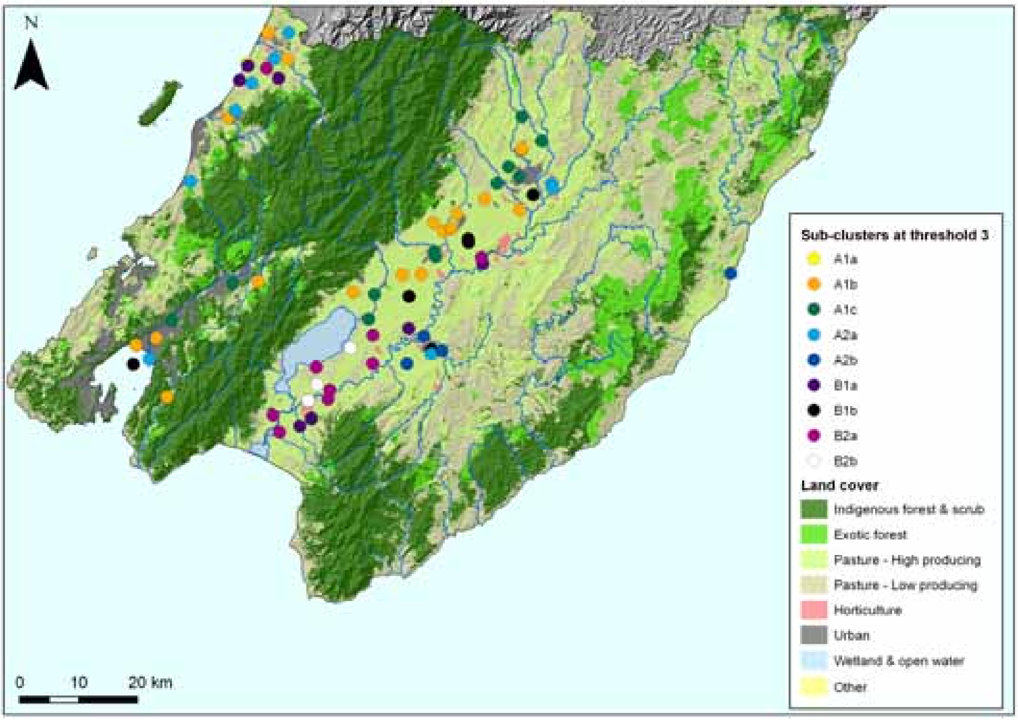


Figure 4.23: Hydrochemical sub-clusters for the 71 GQSoE monitoring bores in the Wellington region, derived from hierarchical cluster analysis, overlaid with land cover from MfE (2010)

The hydrochemistry of sub-clusters A1b and A2a suggests that groundwater is influenced by human activity, with the greatest median concentrations of nitrate, sulphate and *E. coli* found in bores assigned to these sub-clusters. This is to be expected given that A1b and A2a bores are located in unconfined to semi-confined aquifers in areas of intensive agricultural land use where rainfall is the main mode of recharge. Groundwater in these aquifers has more interaction with surface water and water moving through the soil zone, which allows the passage of contaminants into the groundwater. Sub-clusters A1c and A2b are also located in unconfined to semi-confined aquifers where recharge zones are likely to be in areas of intensive land use and show the influence of human activity. However, groundwater typical of these sub-clusters is recharged at greater volumes by river discharge and, particularly in the case of sub-cluster A1c, contaminants and major ion concentrations in the groundwater tend to be lower, probably as a result of dilution and lack of evapotranspiration.

Although hierarchical cluster analysis clearly indicates that human activity influences groundwater quality in the Wellington region, cross-tabulation analysis could only identify statistically significant relationships between sub-cluster hydrochemistry and aquifer lithology and confinement. This is to be expected given groundwater chemistry is directly influenced by surrounding lithology and by the absence or presence of oxygen. In terms of land use, it may be difficult to distinguish between the impacts of different land uses (eg, horticulture vs high producing pasture) and, in any case, groundwater quality is likely to be influenced by land use at the point of recharge rather that land use surrounding the sampling bore. As noted by Daughney and Randall (2009) in national level reporting of groundwater quality state and trends, this highlights the importance of establishing the age and origin of groundwater at GQSoE sites in order to aid interpretation of measured groundwater quality.

Comparison of the median values of nine key indicator variables against relevant guidelines indicates that, in general, groundwater quality in the Wellington region is good. The main variables where median values exceeded their respective DWSNZ (2005) MAVs or GVs were iron, manganese and, to a lesser extent, ammoniacal nitrogen (25, 32 and 5 bores, respectively). In all cases except one, these are cluster B bores located in semi-confined to confined oxygen-poor aquifers that naturally exhibit elevated concentrations of iron, manganese and ammonia (due to rock-water interaction and the redox potential). Only three bores with median values above the DWSNZ (2005) GV (an aesthetic threshold) for iron are used for potable supply.

One bore at Te Horo Beach on the Kapiti Coast recorded a median *E. coli* count well in excess of the DWSNZ (2005) MAV and is clearly impacted by land use at the site. Positive *E. coli* counts were also recorded on at least one sampling occasion in 26 bores, nine of which are used for potable supply. The potential significance of these results for contamination of the underlying groundwater is unclear. Poor bore/well head protection is an issue for 11 of the 26 bores. A further two bores are located in areas where an effluent source may cause bacterial contamination. Contamination due to sampler error could also be a potential contributing factor in some instances.

While median nitrate nitrogen concentrations were below the DWSNZ (2005) MAV of 11.3 mg/L in all 71 bores, several individual sample results exceeded this threshold and median concentrations in 15 bores were classified as either ‘elevated’ or ‘highly elevated’. In addition, median concentrations in 23 bores exceeded the recommended aquatic toxicity threshold of 1.7 mg/L. This highlights the potential for impacts on hydraulically connected surface water bodies, a point that is discussed in detail in Section 6.

The highest nitrate concentrations were recorded in the Te Ore Ore aquifer system north of Masterton and the Waitohu aquifer system on the Kapiti Coast. Both of these aquifer systems have been identified in previous studies as having elevated nitrate concentrations attributed to land use (Tidswell 2008; 2009). Tidswell (2008) also identified elevated nitrate concentrations in the unconfined aquifers of Carterton and South Featherston, while Milne et al. (2010) reported elevated nitrate concentrations in shallow groundwater from intensive land use in the Mangatarere catchment near Carterton. Monitoring results from GQSoE bores indicate groundwater quality in Carterton is still affected by human activity, with median nitrate concentrations in GQSoE bores tending to exceed the 3 mg/L elevated threshold. However, contamination of these aquifers may occur elsewhere in the catchment at the point of recharge.

Based on national groundwater surveys undertaken in 2006 and 2010, pesticide and herbicide contamination is limited – groundwater from just two bores tested positive for pesticides in the last two surveys, with the pesticide concentrations below MAVs. Similarly, one-off testing for heavy metals and metalloids in March 2009 only identified arsenic as a potential concern; dissolved arsenic was present in 20 bores with concentrations in three of these exceeding the DWSNZ (2005) MAV. All three bores are located in deep confined aquifers where dissolved iron concentrations are also elevated. This suggests that the elevated concentrations of arsenic in the groundwater are the result of natural rock-water interaction.

Application of the Drinking WQI classified 34 (48%) of the 71 GQSoE bores as being ‘excellent’ for potable use. The majority of these bores were assigned to A group hydrochemical sub-clusters where despite evidence of human influence, high recharge volumes probably prevent contaminant accumulation in the aquifers. In contrast, the 18 (25%) bores classified as ‘fair’ or ‘poor’ for potable water quality were generally assigned to the B group sub-clusters where natural processes tend to render the groundwater unsuitable for potable use (without treatment). Of the 21 GQSoE bores currently used for potable water supply, 20 were classified as ‘excellent’ or ‘good’ under the Drinking WQI. The one exception was bore S27/0588, which is used for a public water supply by the South Wairarapa District Council (SWDC). This bore failed to meet the dissolved iron aesthetic GV on a regular basis (although SWDC treats the water with ozone prior to reticulation to remove iron and manganese; B Sloan[20], pers. comm. 2012).

The Aquatic Ecosystems WQI only classified five bores (S27/0299) as ‘excellent’ and just over half (36) of the GQSoE bores were rated ‘fair’ or ‘poor’. This reflects the (generally) lower guideline values applicable to assessing aquatic toxicity compared with potable water use, particularly for nitrate and zinc. Water quality guidelines and consideration of effects on hydraulically connected surface waters are discussed further in Section 6.

[20] Bill Sloan, Utilities Manager, South Wairarapa District Council.

5. Groundwater quality – temporal trends

This section presents temporal trends in groundwater quality across the Wellington region, utilising routine GQSoE monitoring data collected quarterly over the period August 2005 to July 2010. The approach to data analysis is outlined first, followed by a summary of the results of trend analyses performed on each of ten key indicators of groundwater quality. The main focus of the results section is on those trends that were deemed both statistically significant and environmentally meaningful.

5.1 Approach to analysis

Ten key variables (considered indicators of human impact, human and ecological health risks and natural groundwater chemistry) were used to assess temporal trends in groundwater quality in the Wellington region. Nine of these variables were also presented in the state analysis in Section 4 (refer to Table 4.2 for the rationale for their selection). The additional variable assessed in this section was dissolved reactive phosphorus (DRP); although not nearly as significant in groundwater as nitrate nitrogen, elevated DRP concentrations have been recorded in shallow unconfined aquifers in some intensive land use areas (eg, Milne et al. 2010) and there may be potential flow-on effects in the surface water ecosystems the aquifers discharge into.

Temporal trend analysis was performed on GQSoE sample results for each of these 10 key indicator variables using R Package V 2.12.0 (The R Foundation for Statistical Computing 2010), NIWA’s TimeTrends software (Version 3.20 2011) and using the statistical principles outlined in Gilbert (1987). The time period for trend analysis was August 2005 to July 2010 inclusive.

Although the groundwater data were screened on the basis of acceptable ion charge balance errors and the presence of outliers (refer Section 2.5.2 for details), due to the limited data set for each variable (n=20 maximum), no data points were excluded from the data set prior to trend analysis. Where a value in the data set for a selected variable was recorded as below the laboratory’s analytical detection limit, this value was replaced with one half the value of the detection limit before performing trend analyses (Scarsbrook & McBride 2007). Where a data set for a variable comprised more than 30% of values below the analytical detection limit, trend analysis was not carried out as results are considered less reliable (Scarsbrook & McBride 2007). This excluded a number of sites and variables from the analysis, most notably *E. coli* in 43 of the 44 bores in which this variable is measured.

All trend analysis was conducted by first examining each variable for seasonality (ie, two seasons) using a Mann-Whitney test. If seasonality was evident, trend analysis was carried out using a Two-Season Seasonal Kendall test with the seasons classified as June to November (winter/spring) and December to May (summer/autumn)[21]. Where no seasonality was evident, trend analysis was performed using the Mann Kendall test.

[21] With only four sample results per year and a five-year reporting period, there would be too few data points for a 4-season (summer, autumn, winter and spring) Seasonal Kendall Test to generate sufficient statistical power for trend detection.

A trend was deemed statistically significant if the *p*-value of the Mann Kendall or Seasonal Kendall test was less than 0.05. In addition to statistical significance, the relative rate of change was assessed by dividing the Sen slope estimator value by the median value of the selected water quality variable. There are no guidelines as to acceptable rates of change in groundwater quality but an arbitrary threshold of 5% was used in this report, with rates of change above this magnitude considered due to anthropogenic influence and therefore environmentally meaningful. This threshold – which compares with an arbitrary 'ecological meaningful' cut-off of 1% for rivers (Scarsbrook 2006) – was drawn from national level groundwater quality state and trend reporting by Daughney and Randall (2009) that found changes in most major and minor elements over the period 1995 to 2008 were less than ± 2% and ± 5% per annum respectively. For nitrate, an additional 'baseline rate of change' criterion from Daughney and Reeves (2006) was used; if the Sen slope indicated an absolute rate of change of greater than ± 0.1 mg/L/yr this was also deemed as being potentially due to anthropogenic influence (and therefore environmentally meaningful).

5.2 Trend results

The temporal trend results are summarised in Table 5.1 and presented in full in Appendix 6. Those trends deemed both statistically ($p<0.05$) and environmentally meaningful (ie, statistically significant and a rate of change >5% per annum or >0.1 mg/L/yr for nitrate nitrogen) are summarised by groundwater bore in Table 5.2. In almost all cases, these trends were derived from the Mann Kendall test (ie, very few of the variables that exhibited seasonality showed any environmentally meaningful increase or decrease in concentration over the reporting period).

Table 5.1: Summary of the results of temporal trend analyses performed for each of 10 groundwater quality variables, based on monitoring data collected from 71 GQSoE bores at quarterly intervals over August 2005 to July 2010[1]

Variable	Deteriorating trends		No trend	Improving trends		Censored sites[2]
	Sig. increase	Meaningful increase		Sig. decrease	Meaningful decrease	
TDS	2	0	61	6	2	0
Nitrite-N	1	1	6	0	0	63
Nitrate-N	1	2	38	0	6[1]	24
Ammonia-N	0	0	24	2	2	43
Iron	0	4	26	1	4	36
Manganese	0	5	42	6	6	12
Lead	0	4	14	0	3	50
Fluoride	0	0	49	10	4	8
DRP	0	6	54	2	3	6
E. coli	0	0	1	0	0	43
Total no.	4	22	315	27	30	285

[1] Three of these trends had a rate of change <5%/year but the absolute rate of change was >0.1 mg/L/yr (See Table 5.2).

[2] A site was deemed censored where >30% of values for the variable of interest were below the analytical detection limit.

Table 5.2: Summary of environmentally meaningful (ie, statistically significant and a relative rate of change >5%/year, or an absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr) temporal trends in 10 groundwater quality variables measured quarterly in 71 GQSoE bores over August 2005 to July 2010 using the Mann-Kendall test and Sen's slope estimator (*=Seasonal Kendall). Bolded and italicised median values exceed DWSNZ (2005) and ANZECC (2000) aquatic toxicity guidelines, respectively.

Bore no.	Variable	*n*	Median	Median annual Sen slope	*p*-value	Rate of change (%/year)
Kapiti Coast						
R25/5165	TDS	19	130.0	-15.433	0.0001	-11.87
	Ammoniacal-N	19	0.24	-0.0285	0.0003	-11.86
	Iron	19	2.89	-0.3534	0.0003	-12.23
	Manganese	19	0.085	-0.012	<0.0001	-14.16
	DRP	19	0.300	0.0156	0.0272	5.19
S25/5256	Nitrate-N	19	*9.60*	-0.2765	0.0290	-2.88
	DRP	19	0.018	0.0011	0.0234	6.30
R25/5135	DRP	19	0.390	0.0350	0.0007	8.98
R26/6503	Manganese	20	0.0133	0.0034	0.0047	25.83
S25/5125	Lead	21	0.0003	-0.0001	0.0020	-44.20
Hutt Valley						
R27/1137	Nitrate-N	20	1.04	0.1998	0.0273	19.22
	Iron	20	0.071	0.0339	0.0077	48.20
	Manganese	20	0.0044	0.0261	0.0022	48.20
R27/1171	Fluoride	16	0.17	-0.0087	0.0340	-5.11
R27/1180	DRP	20	0.012	0.0007	0.0376	5.49
R27/1183	DRP	20	0.009	0.0008	0.0024	8.68
R27/1265	Manganese	20	0.021	-0.0021	0.0124	-10.30
Wairarapa Valley						
S26/0824	Nitrate-N	20	*5.30*	-0.1772	0.0035	-3.34
	Manganese	20	0.0012	-0.0002	0.0051	-15.62
	Lead	20	0.0002	-0.0001	0.0083	-38.19
S27/0495	TDS	19	376.0	-23.237	0.0001	-6.18
	Manganese	19	0.7800	-0.0898	<0.0001	-11.51
	Iron	19	4.90	-0.5798	0.0002	-11.83
S26/0299	Nitrate-N	19	*2.70*	-0.3128	0.0356	-11.58
	Lead	19	0.0004	<0.0001	0.0172	7.42
S26/0705	Lead	20	0.0002	-0.0001	0.0001	-39.17
	Manganese	20	0.0006	-0.0001	0.0158	-16.67
S27/0615	Iron	21	6.90	0.5656	0.0028	8.20
	Manganese	21	0.519	0.0387	0.0037	7.45
T26/0003	Manganese	20	0.0008	0.0001	0.0294	19.72
	Lead	20	0.0002	<0.0001	0.0016	16.09
T26/0538	Nitrate-N	20	*10.05*	-0.3423	0.0158	-3.41
	Manganese	20	0.0015	0.0016	0.0111	108.6
S26/0117	Lead	20	0.0002	0.0001	0.0002	49.92
S26/0439	DRP	20	0.024	-0.0014	0.0107	-5.97
S26/0467	Lead	20	0.0001	<0.0001	0.0022	27.53
S26/0576	Fluoride	18	0.11	-0.0075	0.0131	-6.85
S26/0756	Iron	18	2.65	-0.1503	0.0302	-5.67
S27/0136	Nitrate-N	19	*5.420*	-0.6848	0.0157	-12.64
S27/0202	DRP	20	0.021	-0.0013	0.0107	-6.31
S27/0299	Nitrate-N	20	0.265	0.0188	<0.0001	7.11
S27/0396	Fluoride	19	0.100	-0.0062	0.0276	-6.22
S27/0442	Iron	20	1.17	-0.1466	0.0094	-12.59
S27/0522	Iron	20	0.024	0.0104	0.0081	44.04
S27/0588	Ammoniacal-N	20	0.090	-0.0048	0.0017	-5.38
S27/0594	DRP	17	0.520	0.0860	0.0229	16.54
S27/0607	Manganese	19	1.40	-0.0728*	0.0330*	-5.20*
S27/0681	Fluoride	19	0.110	-0.0066	0.0113	-5.96
T26/0087	DRP	20	0.025	-0.0038*	0.0156*	-15.32*
T26/0099	Nitrate-N	20	*5.600*	-0.5173	0.0016	-9.24
T26/0332	Nitrite-N	20	0.006	0.0006	0.0033	10.90
T26/0413	Iron	20	0.295	0.0487	0.0250	16.52

In all just 83 statistically significant trends (12% out of a total of 683 possible trends[22]) were identified across the 10 water quality variables and 71 GQSoE bores examined (Table 5.1). Of these 83 significant trends, 52 were also considered environmentally meaningful; although these were spread across 36 GQSoE bores, only 10 bores exhibited an environmentally meaningful trend in more than one variable (Table 5.2).

Most (69%) of the 52 environmentally meaningful trends were observed in four variables: dissolved manganese (11 bores), dissolved iron (8 bores), DRP (9 bores), and nitrate nitrogen (8 bores). Further, over half (58%) of the environmentally meaningful trends reflected decreases in the concentration of a specific water quality variable, and so are considered improving trends (Table 5.2).

5.2.1 Dissolved iron and manganese

As noted in Section 4.2.2(e), iron and manganese frequently co-occur in groundwater under oxygen poor conditions and can be examined together. Meaningful increases and decreases in the concentrations of iron were found in four bores each. Manganese concentrations followed a similar pattern, with five bores exhibiting meaningful increases and six bores showing meaningful decreases. In four bores (R25/5165, R27/1137, S27/0495 and S27/0615), iron and manganese concentrations increased or decreased together (Figure 5.1) and generally at a very similar percentage rate of change (Table 5.2).

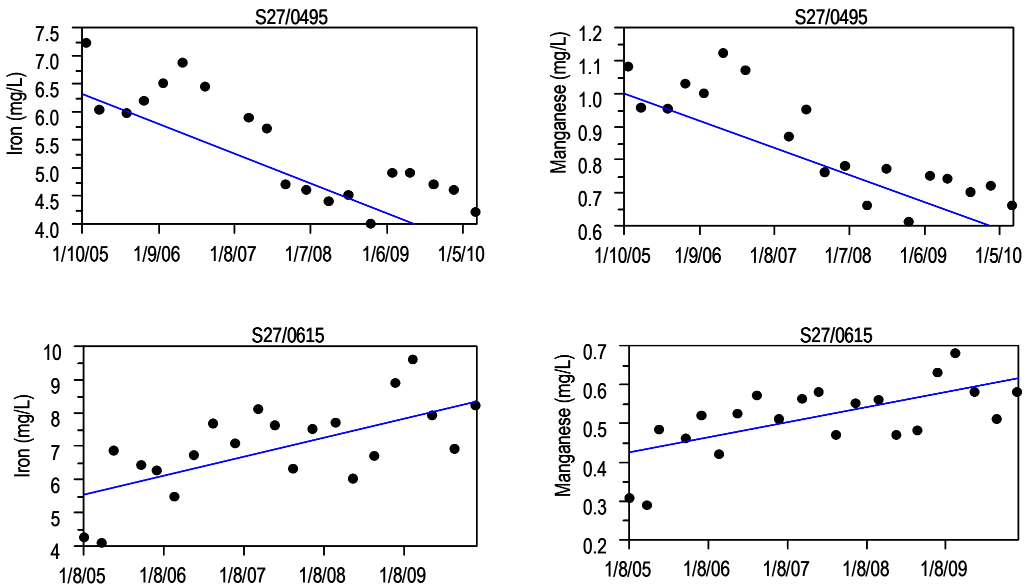


Figure 5.1: Statistically significant and environmentally meaningful decreasing (top) and increasing (bottom) trends in dissolved iron and manganese concentrations recorded in bores S27/0495 and S27/0615 (respectively) between August 2005 to July 2010. The blue line indicates the Mann Kendall slope trend line. Note the different scale ranges used on the *y*-axes.

22 This increases to 20.9% if the 285 data sets containing >30% censored values are removed.

With the exception of bore R25/5165 located at Te Horo Beach on the Kapiti Coast, most of the bores with already elevated median concentrations of iron or manganese that exhibited meaningful increases or decreases in concentration over August 2005 to July 2010 were located in deep confined aquifers in the mid to lower Wairarapa Valley. As noted in Section 4.1.3, bores in these aquifers are assigned to B group hydrochemical sub-clusters and tend to be oxygen-poor, with naturally elevated concentrations of iron and manganese.

The reasons for the observed trends are not clear. It is possible that the groundwater flow pattern is constant but the composition of groundwater passing the GQSoE sites is changing (eg, a change in dissolved oxygen or organic carbon content). Alternatively, it is possible that the composition of the groundwater is constant but the flow pattern has changed (eg, as a result of a climate cycle or possibly a change in water abstraction over a fairly large area).

5.2.2 Dissolved reactive phosphorus (DRP)

Meaningful trends in DRP concentrations were found in nine bores, with six of these bores demonstrating an increase in DRP concentration over the five-year reporting period. The largest magnitude increase was recorded in bore S27/0594 located in a confined aquifer in the lower Wairarapa Valley (0.086 mg/L/yr or 16.5%/year). This bore also had the highest median DRP concentration of the nine bores that exhibited meaningful trends (0.52 mg/L). Of the decreasing DRP trends, the largest was recorded in bore T26/0087 in the upper Wairarapa Valley near Masterton (-0.0038 mg/L/yr or -15.5%/year).

The reasons behind the observed trends are not clear, but it is noted that five of the six meaningful increasing trends were observed in bores located in confined aquifers. In two cases, the median concentrations are high enough to suggest that the trends might possibly be linked with natural rock interaction. In the case of bore R25/5165 (unconfined), it is possible that effluent from septic tanks is contributing to the increasing DRP concentrations. This requires further investigation.

5.2.3 Nitrate nitrogen (nitrate)

Meaningful decreases in nitrate concentrations were found in six bores (Table 5.2, Figure 5.2), including three in the upper Wairarapa Valley and two in the middle Wairarapa Valley. Three of these bores (S26/0299, S27/0136, T26/0099) exhibited decreasing trends in nitrate concentrations of a magnitude greater than 5% (11.6%, 12.6% and 9.2%, respectively). The remaining two bores (S26/0824 and T26/0538), along with bore S25/5256 south of Otaki on the Kapiti Coast, recorded decreasing trends in nitrate concentrations at an absolute rate exceeding 0.1 mg/L/yr (-0.18, -0.34 and -0.28 mg/L/yr, respectively). Decreasing concentrations of nitrate in all instances are most likely due to a reduction of nitrate contamination in the recharge areas, especially at Otaki (bore S25/5256). This is discussed further in Section 5.3.

Two bores, one located in the unconfined river gravels in Upper Hutt (bore R27/1137) and one located in a confined aquifer near Lake Wairarapa (bore S27/0299), recorded meaningful increases in nitrate concentrations (19.2% and 7.1% respectively, Figure 5.2). The reasons behind these trends are not known.

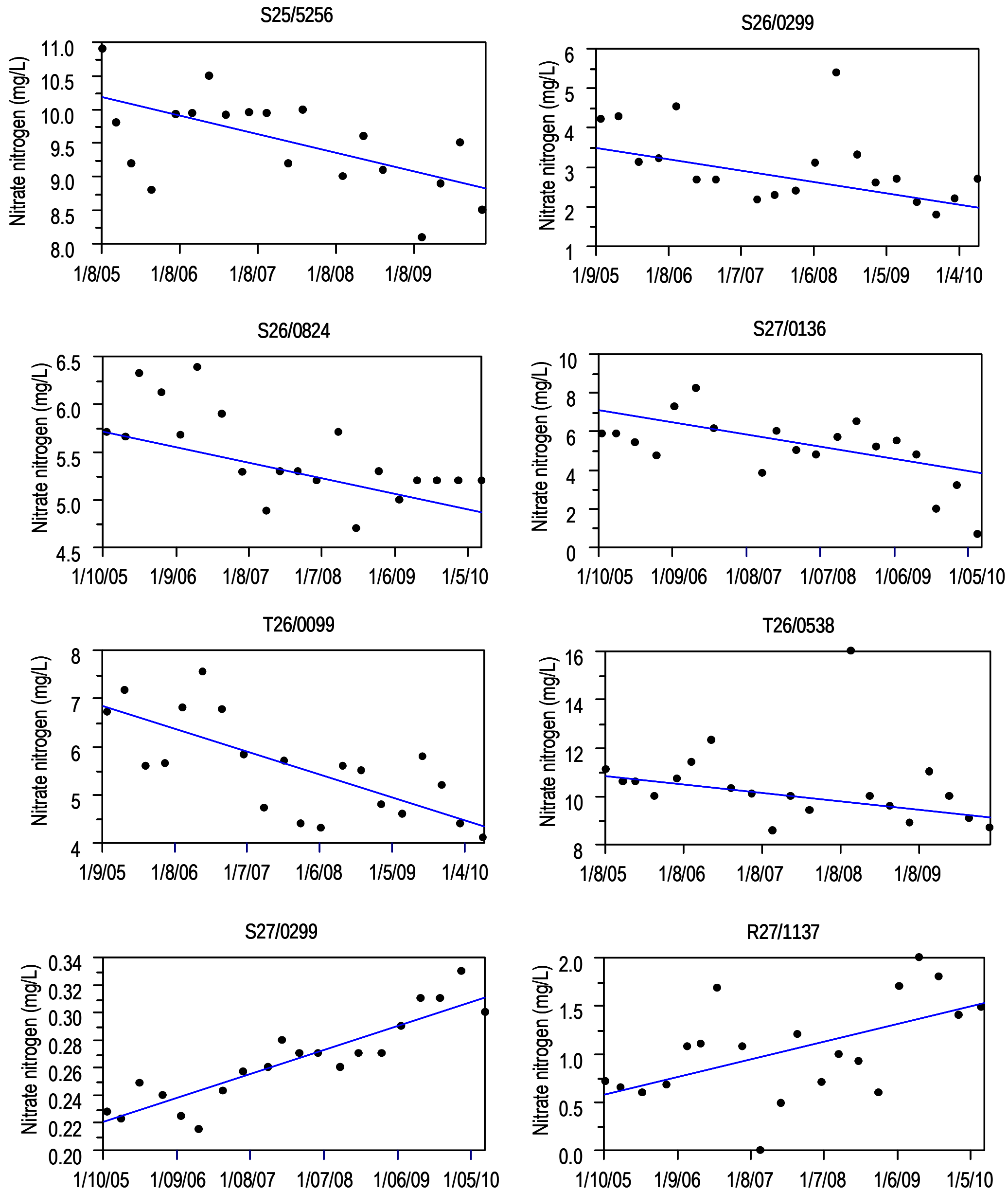


Figure 5.2: Statistically significant and environmentally meaningful trends recorded in nitrate nitrogen concentrations recorded in GQSoE bores sampled quarterly over August 2005 to July 2010. The blue line indicates the slope and magnitude of the Mann Kendall trend line. Note the different scale ranges used on the *y*-axes.

The confined nature of bore S27/0299 suggests that there has perhaps been a change at this site that has resulted in a shift towards a slightly oxidising environment. The median nitrate concentrations in both bores are low and well below guideline thresholds.

5.3 Environmental significance

While all of the 52 trends listed in Table 5.2 are considered environmentally meaningful (ie, statistically significant and a rate of change of >5% per year), based on the median values recorded over the five-year reporting period, none pose a concern from a drinking water perspective. Just three bores listed in

Table 5.2 (S27/0495, S27/0607 and S27/0615) exceeded the DWSNZ (2005) MAV for manganese (also recording median iron concentrations above the DWSNZ (2005) GV), none of which are used for potable purposes. Similarly, none of the other bores with median concentrations that exceeded the DWSNZ (2005) iron GV (R25/5165, S26/0756 and S27/0442 and T26/0413) are used for potable purposes.

Mostly decreasing (ie, improving) trends in nitrate concentrations were observed and likely reflect a reduction of nitrate contamination in the recharge areas. In several cases, the trends observed over 2005 to 2010 are a continuation of a longer-term trend. For example, nitrate concentrations in bore S26/0299 near Masterton have been steadily decreasing since monitoring began in 1998 (Figure 5.3), and may be linked to the closure of a chicken farm upgradient of the bore (L. Annear[23], pers. comm. 2012).

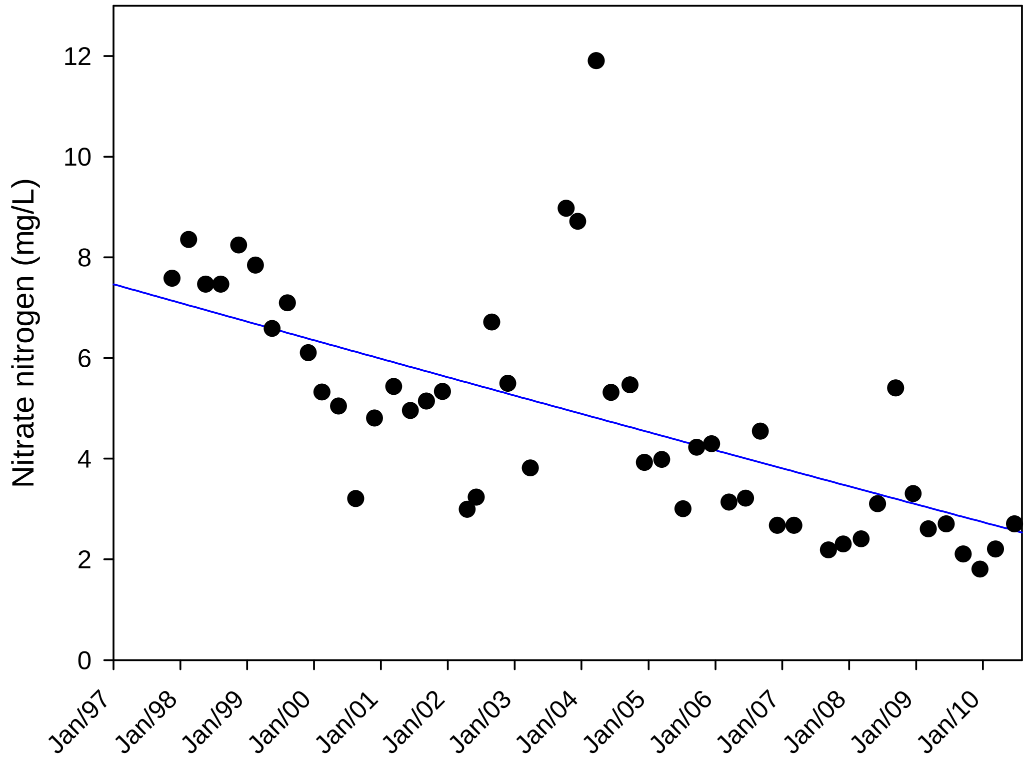
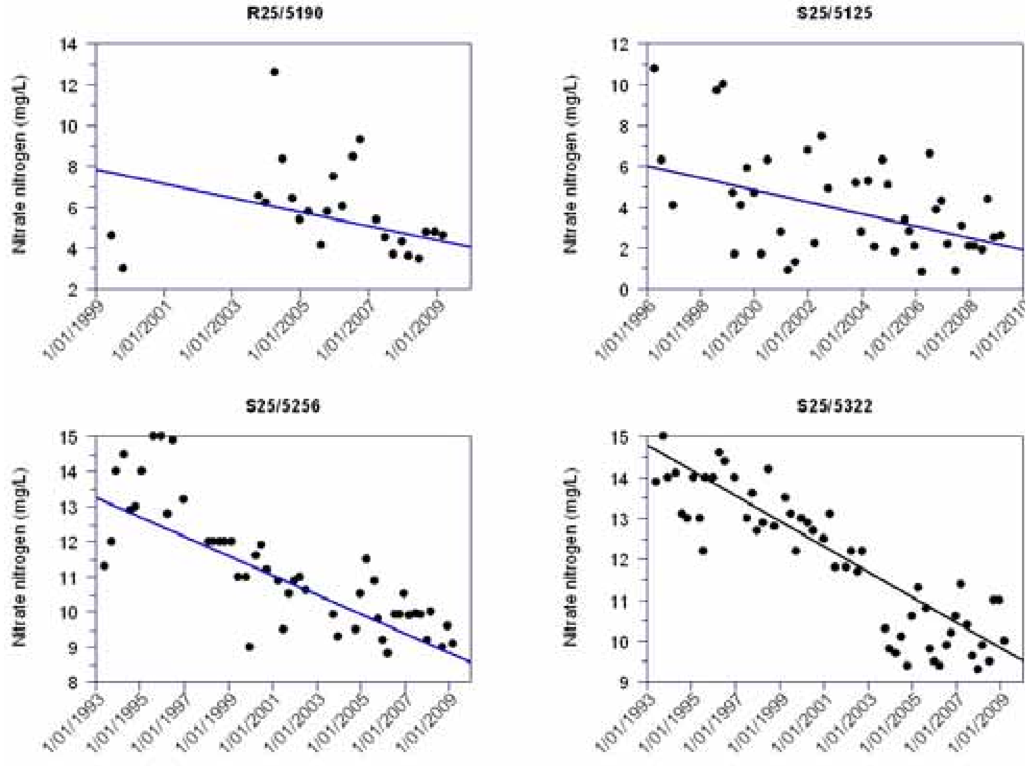


Figure 5.3: Nitrate nitrogen concentrations recorded in GQSoE bore S26/0299, 1998 to 2010 inclusive. The blue line indicates the slope and magnitude of the Mann Kendall trend line. A statistically significant (p<0.001) decrease of 0.359 mg/L/yr was recorded over this time period.

Similarly, the decrease in nitrate concentrations observed in bore S25/5256 on the Kapiti Coast are consistent with the results from a targeted investigation of nitrate concentrations at 31 locations across the northern Kapiti Coast in late 2008 (Tidswell 2009). This investigation found that groundwater bores tested in 2008 had lower concentrations of nitrate than bores sampled in an earlier survey in 1996 (reported by Hughes (1997)). As part of the investigation, Tidswell (2009) performed trend analyses on nitrate data from 10 GQSoE

[23] Lindsay Annear, Senior Environmental Monitoring Officer, Greater Wellington.

bores sampled in the area, with the trend period spanning the entire length of record from the date of first monitoring (generally 1993 but as late as 1999 in one bore) up until March 2009. The results revealed statistically significant and environmentally meaningful decreasing trends in nitrate concentrations in three irrigation bores located in areas of horticulture (S25/5256, S25/5125 and S25/5322) and one bore located in an area of agriculture (R25/5190[24]) (Figure 5.4). The absolute rate of change for bore S25/5256 reported in Table 5.2 for August 2005 to July 2010 (-0.28 mg/L/yr) is the same as that reported by Tidswell (2009) for the longer reporting period of May 1993 to March 2009. Although median nitrate concentrations in GQSoE bores S25/5125, S25/5322 and R25/5190 also declined over 2005 to 2010 (see Appendix 6), none of these decreases were statistically significant over this time period.



(Source: Reproduced from Tidswell (2009), p27)

Figure 5.4: Nitrate nitrogen concentrations recorded in four GQSoE bores sampled over 1993 to 2009. The blue line indicates the Mann Kendall slope trend line. Statistically significant decreases (p<0.001–p=0.01) ranging from -0.28 to -0.31 mg/L/yr were recorded in bores S25/5256, S25/5125 and S25/5322 and a significant decrease (p=0.07) was recorded in bore R25/5190 (-0.35 mg/L/yr).

The reasons for the decreasing trends in nitrate concentrations recorded on the northern Kapiti Coast are not known with any certainty but Tidswell (2009) cited anecdotal evidence that the decreases are probably due to changes in land use and land management practices, including improved management of fertiliser application. Recharge influence from the Otaki River was also cited as a contributing factor for the decreasing nitrate concentrations in bore S25/5125. Tidswell (2009) further noted that while nitrate concentrations had decreased significantly in some bores – from once regularly exceeding the

24 In the case of bore R25/5190, the trend was just outside the standard threshold for statistical significance (p<0.05) (refer Figure 5.4).

DWSNZ (2005) MAV of 11.3 mg/L to only occasional exceedences in recent years – groundwater concentrations still remain elevated in some areas which historically had nitrate contamination, particularly those located in the Waitohu and Hautere groundwater management zones. Based on the median nitrate concentrations reported in GQSoE bores S25/5256, S25/5322 and R25/5190 in Section 4.2.2, this observation remains valid. On this note, despite most of the nitrate trends reported in Table 5.2 representing an improving trend (with the only increasing trends recorded in two bores where the median values fall 1–2 orders of magnitude below drinking water and aquatic toxicity thresholds), median nitrate concentrations in two bores (one of which is S25/5256) are highly elevated (>7 mg/L). In addition, median concentrations in six bores significantly exceed the 1.7 mg/L aquatic toxicity threshold recommended by Hickey and Martin (2009).

In terms of DRP, as outlined in Section 4.3.1, the ANZECC (2000) lowland trigger value of 0.010 mg/L is considered overly conservative for application to groundwater quality. In any case, only four of the nine bores that recorded meaningful trends in DRP concentrations (R25/5165, S26/0439, S27/0202 and T26/0087) are located in unconfined aquifers – where there is actual or potential interaction with surface water – and three of these bores exhibited declining DRP concentrations.

It is important not to overstate the absence of many statistically significant and environmentally meaningful trends in the GQSoE monitoring results. While almost 80% of the 398 trend test results able to be generated fell into this category, the absence of environmentally meaningful trends can not be considered in isolation from the actual median values reported for each water quality variable. This is particularly important in the case of nitrate, which as reported in Section 4.2.2(c) and discussed further next in Section 6, is present at elevated concentrations in over 20% of the 71 GQSoE bores.

6. Discussion

This section revisits the main findings from the groundwater quality state and temporal trend analyses presented in Sections 4 and 5, respectively. These findings are first presented as a regional overview that is then placed in a national context. Some key factors that influence the interpretation of groundwater quality assessments are discussed, along with the need to consider interactions between surface water and groundwater when evaluating groundwater quality. Monitoring limitations and knowledge gaps are also outlined.

6.1 Regional overview

6.1.1 State

Analysis of GQSoE data over the period August 2005 to July 2010 indicates that from a drinking water perspective, groundwater quality in the Wellington region is generally very good. Of the nine key indicator variables examined, the main two that recorded median values above their respective DWSNZ (2005) MAVs or GVs were iron and manganese (in 25 and 32 bores, respectively). These exceedences were generally limited to bores located in semi-confined to confined oxygen-poor aquifers that naturally exhibit elevated concentrations of these elements (as a result of longer residence time within the aquifer and greater rock water interaction). Only three of the bores with median iron concentrations above the GV are used for potable supply; none of the bores with elevated manganese concentrations are used for potable supply. Similarly, none of the five GQSoE bores with median ammoniacal nitrogen concentrations above the DWSNZ (2005) GV are used for potable supply.

One bore at Te Horo Beach on the Kapiti Coast recorded a median *E. coli* count well in excess of the DWSNZ (2005) MAV and is clearly impacted by land use at the site. Positive *E. coli* counts were also recorded on at least one sampling occasion in 26 bores, nine of which are used for potable supply. Poor well head protection and close proximity to an effluent source are the most likely causes of *E. coli* contamination in eleven and two of the 26 bores, respectively.

Surveys undertaken in 2006 and 2010 indicate that there is limited pesticide and herbicide contamination of groundwater in the Wellington region. A one-off assessment of heavy metals and metalloids in March 2009 found dissolved concentrations of arsenic were present in 20 bores, with concentrations in three of these exceeding the DWSNZ (2005) MAV. However, all three bores were located in confined aquifers (where dissolved iron concentrations are also elevated), suggesting that the elevated concentrations of arsenic in the groundwater are consistent with natural rock-water interaction. No significant contamination issues were identified for other heavy metals and metalloids tested.

Application of the Drinking WQI classified 53 (75%) of the 71 GQSoE bores as being 'good' or 'excellent' for potable use; of the remaining 18 bores classified as 'fair' or 'poor', just one is currently used for potable supply. In contrast, classifications assigned to the GQSoE bores using the Aquatic

Ecosystems WQI showed that just under half (49%) of the bores were ‘good’ or ‘excellent’, with a significant number of bores (13) graded as ‘poor’ (indicating the potential for adverse effects on aquatic ecosystems in hydraulically connected surface waters). This reflects the fact that the thresholds for aquatic toxicity, particularly in the case of nitrate nitrogen, are considerably lower than those for potable water supply; none of the 71 GQSoE bores recorded a median nitrate concentration above the DWSNZ (2005) MAV but, in 23 cases, the median exceeded the aquatic ecosystems toxicity threshold of 1.7 mg/L. Water quality guidelines and consideration of effects on hydraulically connected surface waters are discussed further in Section 6.4.

6.1.2 Temporal trends

Temporal trend analyses performed across 10 water quality variables on GQSoE data collected over August 2005 to July 2010 revealed a relatively small number (52 or 7.6%) of environmentally meaningful trends (ie, statistically significant <u>and</u> a relative rate of change >5%/year, or an absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr). The majority of these trends were associated with just four variables: dissolved manganese (11), dissolved iron (8), dissolved reactive phosphorus (DRP, 9) and nitrate nitrogen (8). Further, over half (58%) of the environmentally meaningful trends reflected decreases in the concentration of a specific water quality variable and, therefore, can be considered representative of improving trends.

While an approximately equal number of meaningful increases and decreases were observed in the concentrations of dissolved manganese and iron, six of the nine DRP trends reflected increasing concentrations, with absolute rates of change ranging from 0.0011 to 0.0860 mg/L/yr. In contrast, six of the eight meaningful trends for nitrate were associated with decreasing concentrations (ranged from -0.18 to -0.69 mg/L/yr).

The reasons for the observed increases and decreases in iron, manganese and DRP concentrations are unclear without further investigation but could be due to changing groundwater flow paths, changes in concentration in the recharge water, or a combination of both. In terms of nitrate, the observed decreasing trends are likely to be caused by changes in concentration in the recharge zone. In the case of bore S25/5256 on the northern Kapiti Coast, the decreasing trend in nitrate concentrations is consistent with that reported by Tidswell (2009) and appears to reflect significant decreases in groundwater nitrate concentrations across a relatively large area south and north of Otaki. Much of this area has a history of intensive land use, including horticulture and agriculture, and it is possible that the decreasing nitrate concentrations reflect changes in land or fertiliser use over time. In any case, the decreases represent a significant improvement; nitrate concentrations in bore S25/5256 once regularly exceeded the DWSNZ (2005) MAV of 11.3 mg/L but, since August 2005, the MAV has not been exceeded once (maximum 10.9 mg/L).

6.2 National context

A comparison of the GQSoE monitoring results presented in this report against state and trend information presented in a recent national groundwater report (Daughney & Randall 2009) indicates that groundwater quality in the Wellington region is relatively high. In their report, Daughney and Randall (2009) examined state and trends in regional groundwater and National Groundwater Monitoring Programme (NGMP) data-sets over the period 1995 to 2008. Here, the findings from this report and the national report are compared for the two core Ministry for the Environment (MfE) indicator variables, nitrate nitrogen (nitrate) and *E. coli*. While some caution is clearly needed given the different data sets used, the two reports used similar methodologies and so the comparisons are considered indicative; the national report did also include a regional breakdown that can be utilised to better inform the comparison.

6.2.1 Nitrate nitrogen (nitrate)

Daughney and Randall (2009) reported a national median nitrate concentration of 1.7 mg/L based on all data collected over 1995 to 2008.[25] This compares with a median concentration of 0.5 mg/L for the Wellington region for the same period (Daughney & Randall 2009) and a median concentration of 0.45 mg/L for August 2005 to July 2010 (this report). In all, 23 of 71 GQSoE bores recorded a median value above the national median concentration in the five-year period ending 31 July 2005.

In terms of temporal trends, Daughney and Randall (2009) reported statistically significant trends in nitrate concentrations at approximately one third of the monitoring sites across New Zealand; of these, twice as many sites displayed increasing trends compared to decreasing trends. In contrast, this report only identified statistically significant trends at nine sites (13%), with six of these representing decreasing nitrate concentrations.[26] This suggests that intensification of agricultural land use (whether past or present), which has been identified both nationally and internationally as the likely cause for increasing trends in groundwater nitrate concentrations (eg, Daughney & Reeves 2006), is not yet resulting in a significant deterioration in groundwater quality in the Wellington region. Certainly, although there are clearly some localised areas of nitrate contamination in the Wellington region, the regional median nitrate concentration is much lower than that quoted by Daughney and Reeves (2009) for regions such as Waikato (4.2 mg/L), Southland (3.4 mg/L) and Canterbury (3.4 mg/L). Some caution is needed with this comparison; while much of the land in these regions is used for intensive agriculture, including significant amounts of dairying, this may also mean that groundwater quality monitoring in these regions is biased towards measuring the impacts of this intensive land use (ie, groundwater monitoring networks may target areas where contamination problems are likely).

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[25] Daughney and Randall (2009) note that data from the Gisborne region were missing from the analysis and that the national median of 1.4 mg/L reported by Daughney and Wall (2007) for the period 1995 to 2006 may be more representative.

[26] For the Wellington region between 1995 and 2008, Daughney and Randall (2009) reported statistically significant increasing and decreasing trends in nitrate in 4 and 14 bores, respectively.

6.2.2 E. coli

Daughney and Randall (2009) reported a national median *E. coli* concentration of <1 cfu/100 mL based on all groundwater data collected over 1995 to 2008. Just over 23% and 2% of the monitoring sites examined recorded median *E. coli* counts above the DWSNZ (2005) MAV for human consumption (<1 cfu/100mL) and the ANZECC (2000) trigger value for livestock consumption (100 cfu/100mL), respectively. Based on GQSoE monitoring data collected over August 2005 to July 2010, the median *E. coli* count in the Wellington region was also <1 cfu/100mL but only one of the 44 bores tested for this indicator (2.3%) recorded a median count above the DWSNZ (2005) MAV for human consumption.

Daughney and Randall (2009) did not detect many temporal trends in *E. coli* counts at the national level and noted that temporal comparisons in *E. coli* data were difficult to make due to the use of proxy indicator variables such as total coliforms in some regions (including Wellington) during a portion of the reporting period. In addition, as was the case in this report, most data sets generally contained a disproportionately large number of censored values that make meaningful trend analysis difficult.

6.3 Interpretation of groundwater data

Although state and trend analyses in groundwater quality were presented in separate sections in this report, information from both needs to be considered together for accurate interpretation of groundwater quality. In addition, the time periods for analysis and guidelines used are also important.

6.3.1 Consideration of state and trend data together

It is important to consider the results of both state and temporal trend analyses together, in particular to look at trends in the context of median values. For example, based on the median values recorded over the August 2005 to July 2010 reporting period, none of the 44 environmentally meaningful temporal trends identified in GQSoE bores over this period pose a concern from a drinking water perspective. Conversely, while the overall lack of environmentally meaningful trends (only 13% of the 398 trend test results able to be generated) suggests there has been little change in overall groundwater quality in the Wellington region between August 2005 and July 2010, when the median concentrations for each variable across all 71 GQSoE bores were also considered, it is evident that there are some areas of concern. This is probably most significant in terms of nitrate. For example, although significant temporal trends were only identified in half of the 10 GQSoE bores with the highest median nitrate concentrations, in all 10 bores the median concentrations fall in the elevated to highly elevated range (4.8 to 11.0 mg/L) and pose a potential concern for hydraulically connected surface waters. This is discussed further in Section 6.4.

In addition to assessing median results, individual sampling results can also be important. For example, of the 44 bores monitored for *E. coli*, 26 returned detectable levels on at least one sampling occasion (equating to an exceedence of the DWSNZ (2005) MAV). Therefore, despite only one bore recording a median count above the MAV and temporal trends not being able to be examined, faecal contamination is clearly present at times. Whether this translates to contamination of the underlying groundwater is unclear; poor well head protection or close proximity to an effluent source can often cause bacteria contamination in bores. As noted in Section 6.1.1, poor well head protection probably explains positive *E. coli* counts in almost half of the 26 bores.

6.3.2 Time periods for analysis

The time period adopted for state and trend analyses can significantly influence the results of the analyses. This is particularly the case for temporal trend analysis which requires a sufficient number of data points to generate adequate statistical power for robust assessment of trends. The five-year trend assessment period applied in this report, although necessary for practical reasons (refer Section 2.5), produced a relatively small data set and it is possible that some potentially significant trends may not have been detected over this period. For example, Tidswell (2009) reported significant decreases in nitrate concentrations in four GQSoE bores on the northern Kapiti Coast over the period 1993 to 2009, but, in the present report covering August 2005 to July 2010, the decreasing trends were only deemed significant in one of these bores.

6.3.3 Guidelines

A comparison of the classifications assigned to the 71 GQSoE bores under the Drinking WQI and Aquatic Ecosystems WQI highlights that there are significant differences in guideline values used to assess groundwater quality for different purposes. In New Zealand, groundwater quality data have traditionally been assessed against the national drinking water standards for human consumption, despite the fact that a considerable amount of groundwater is not used for this purpose. In recent national groundwater quality assessments (eg, Daughney & Wall 2007; Daughney & Randall 2009), median concentrations for selected variables, notably nutrients, have also been compared against ANZECC (2000) guidelines. These guidelines cover a range of purposes, including stock water, aquatic toxicity and general ecosystem health, resulting in quite widely varying trigger values. In the case of nitrate – one of the core national reporting indicators – ANZECC (2000) specify a general trigger value of 0.444 mg/L (as nitrite-nitrate nitrogen) for lowland rivers, but aquatic toxicity and stock water trigger values of 7.2 mg/L (95% species protection level (and recently revised to 1.7 mg/L as nitrate-nitrogen by Hickey and Martin (2009)) and 90 mg/L (also as nitrate-nitrogen), respectively.

It would be beneficial if more direction was provided at the national level around standards and guidelines for groundwater quality reporting. For the reasons outlined next in Section 6.4, more consideration should be given to reporting nitrate concentrations at thresholds of relevance to aquatic ecosystems; these are generally an order of magnitude below the human drinking water standards. Consideration also needs to be given to how best to meaningfully report on groundwater that naturally exceeds guideline values; for example, the majority of GQSoE bores that recorded median dissolved iron or manganese concentrations above DWSNZ (2005) or ANZECC (2000) guidelines are located in semi-confined to confined oxygen-poor aquifers that exhibit elevated concentrations of these elements as a result of natural rock-water interaction under redox conditions and longer residence times within the aquifer.

6.4 Surface water/groundwater connections

There are extensive hydraulic connections between surface and ground waters in the Wellington region, particularly in the shallow unconfined and semi-confined aquifers. This has been demonstrated through both concurrent river and stream guagings (eg, Gyopari & McAlister 2010a, 2010b & 2010c) as well as through analysis of groundwater and surface water chemistry (eg, Daughney 2010). These hydraulic connections can vary seasonally and, in some instances, the dominance of recharge sources can switch between river and rainfall.

Many of the region’s shallow unconfined and semi-confined aquifers are located in areas of intensive agricultural land use where interaction with water moving through the soil zone allows contaminants to pass from the overlying soil into the groundwater. As summarised in Section 4.4, this can be seen in GQSoE bores assigned to hydrochemistry sub-clusters A1b and A2a which had the greatest median concentrations of nitrate, sulphate and *E. coli*. In terms of nitrate, which is highly mobile in soils, data in Section 4.2.2 and reported in numerous targeted water quality investigations in the region (eg, Tidswell 2008; Milne et al. 2010), highlight that concentrations in groundwater are generally higher in the winter months when rainfall is greater, soils are more saturated and groundwater levels higher. This raises concern where groundwater with elevated nitrate discharges to surface waters, such as in the intensively farmed Mangatarere and Parkvale stream catchments near Carterton. Perrie et al. (2012) reported median nitrate concentrations (as nitrite-nitrate nitrogen) ranging from 1.20 mg/L to 4.35 mg/L at Greater Wellington’s three river SoE monitoring sites in these catchments for the three-year period ending in June 2011. As well as these median concentrations being elevated from both a regional and national perspective (Milne et al. (2010)), of particular concern is the relatively high proportion of nitrate results that exceeded the Hickey and Martin (2009) aquatic toxicity threshold of 1.7 mg/L (16.7 to 100% across the three SoE sites).

Figure 6.1, which presents a graphical summary of median nitrate concentrations in the 71 GQSoE bores monitored over August 2005 to July 2010, highlights the extent to which groundwater nitrate concentrations exceed the aquatic toxicity threshold. It also highlights that there are 15 bores in which median concentrations are considered to be ‘elevated’ (or ‘highly elevated’) due to human impact. Note that while the elevated threshold was set at 3 mg/L (refer to Section 4.2.1), Daughney and Reeves (2005) defined nitrate thresholds of >1.6 mg/L and >3.5 mg/L as ‘probably’ and ‘almost certainly’ indicative of human influence, respectively; this suggests that the 23 bores with a median concentration above the aquatic toxicity threshold of 1.7 mg/L are probably being impacted by human activity.

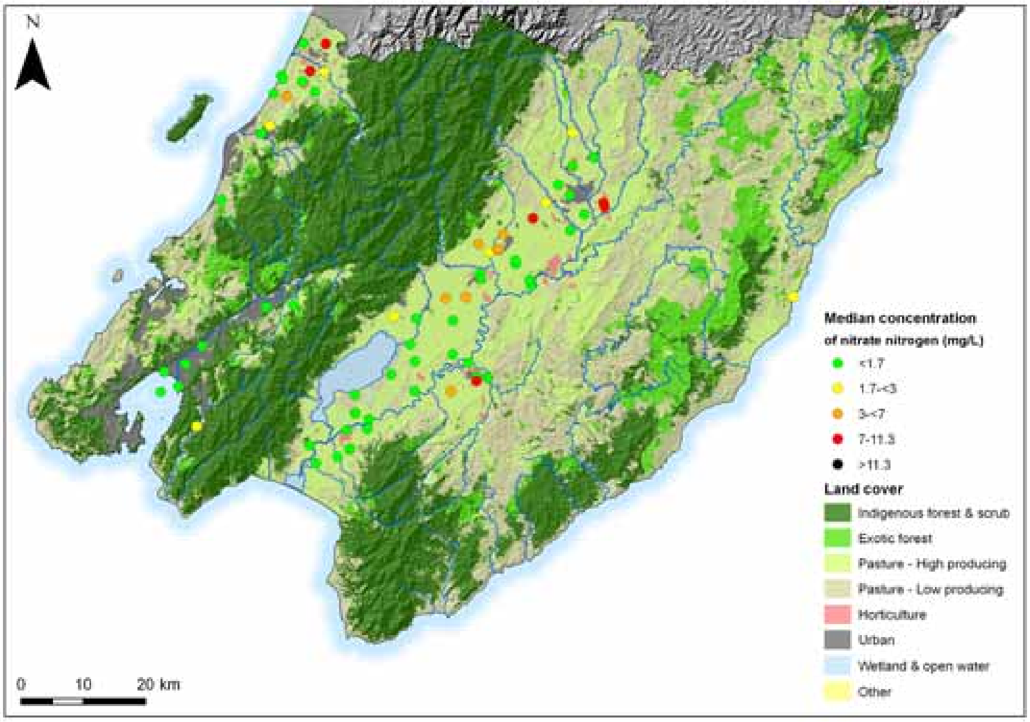

Figure 6.1: Median nitrate nitrogen concentrations for 71 GQSoE bores sampled quarterly over August 2005 to July 2010

As outlined in Section 4.2.2(c), of the 23 bores with median nitrate concentrations above the 1.7 mg/L aquatic toxicity threshold, 17 are located in unconfined to semi-confined aquifers where there is an increased likelihood of discharge to surface water. While discharge of nitrate-enriched groundwater clearly has an impact on surface water quality in the Mangatarere and Parkvale Stream catchments (Perrie et al. 2012), potential impacts from nitrate-enriched groundwater discharge in other catchments in the Wellington region are largely unknown. The regional median nitrate (as nitrite-nitrate nitrogen) concentration recorded across 55 river and stream SoE water quality monitoring sites sampled monthly over the three years ending 30 June 2011 is 0.21 mg/L (Perrie et al. 2012), suggesting that groundwater discharge into most surface water environments would be sufficiently diluted such that nitrate concentrations would not lead to aquatic toxicity issues. A possible exception might be during low flows in some streams where groundwater contributes the majority of baseflow. This possibly occurs in the Parkvale Stream catchment. Daughney (2010) reported that the water chemistry at surface water site RS45 in this catchment has the same hydrochemical signature as moderately evolved groundwater in the Parkvale aquifer. This suggests that the Parkvale Stream is fed predominantly by groundwater from the Parkvale aquifer.

Irrespective of whether or not groundwater nitrate inputs are sufficiently diluted in surface waters to avoid aquatic toxicity issues, this does not mean that the groundwater nutrient inputs are sufficiently diluted to prevent enrichment-related effects such as contributing to periphyton proliferations. See Perrie et al. (2012) for further discussion.

Despite clear evidence of land use impacts on groundwater quality in some parts of the Wellington region, a statistically significant relationship between groundwater chemistry and bore location or surrounding land use could not be identified. This has also been reported in national level groundwater quality analysis (eg, Daughney & Reeves 2005) and is attributed to groundwater quality probably being influenced by land use at the point of recharge rather that land use surrounding the sampling bore. Daughney and Randall (2009) noted in their national level report on groundwater quality state and trends that determining the impacts of land use could be assisted by establishing the age and origin of groundwater at monitoring sites.

Although determination of groundwater age and origin is a relatively expensive and time-consuming exercise it would certainly generate useful information. For example, in March 2010, following completion of the monitoring component of the Mangatarere Stream catchment investigation, near base flow water samples were collected from the lower reaches of the stream and its main tributaries and tested for stable isotopes and tritium (Tidswell et al. 2010). The aim of this exercise was to identify the age and source of water entering the stream as an indication of the relationship between nutrient contamination and land use. While the results were inconclusive, water flowing in the Mangatarere Stream was estimated at approximately two years old with its source being rainfall from in the Tararua Range. This suggests that a portion of the water flowing in the Mangatarere Stream was groundwater, recharged by surface water infiltration. Further, its estimated age suggests that nutrient contamination in the groundwater is due to relatively recent land use practices. (Tidswell et al. 2010). If this is the case, then improving current land use practices in the catchment may improve the health of the Mangatarere Stream in a relatively short period of time.

Overall, based on the land use information presented in Section 3.3.2(a), further land use intensification is expected in the Wellington region in the future, particularly in some parts of the Wairarapa. Given this, and the high degree of surface and groundwater connection that exists in many areas, it is critical that any intensification utilises best practice land management practices to minimise adverse impacts on underlying groundwater and connected surface water resources. Continued monitoring of soil, groundwater and surface water quality is also needed since there are often long time lags associated with groundwater entering surface water.

6.5 Monitoring limitations and knowledge gaps

Greater Wellington's GQSoE monitoring programme provides valuable information about the quality of groundwater in the Wellington region. However, there are several limitations with the programme that make it difficult to accurately interpret groundwater quality and changes in its condition over time, and the potential for groundwater to impact on the quality and ecology of surface water systems:

- Groundwater bores are not evenly distributed spatially to represent types of aquifer confinement in all areas of the Wellington region. Therefore, information on the chemical properties of some aquifers is lacking and the results of spatial hydrochemistry analyses – such as those presented in Section 4.1 – could be biased where there is a dominance of one particular aquifer type in one area. The recent re-evaluation of groundwater resources in the Wairarapa Valley, which culminated in a proposed new framework to manage hydraulically connected ground and surface waters (Hughes & Gyopari 2011), provides an opportune time to review the existing suite of GQSoE monitoring bores, alongside the proposed review of existing surface and groundwater hydrological monitoring sites. The review of GQSoE monitoring sites should also be undertaken alongside the re-assessment of existing river water quality monitoring sites (Perrie et al. 2012).

- As is the case with most regional groundwater monitoring networks, the GQSoE monitoring network comprises largely privately owned bores and some of the contamination recorded in these bores, most notably *E. coli* contamination, may actually be an artefact of poor borehead protection rather than a reflection of the quality of the underlying groundwater quality. In addition, access to privately owned bores is not always possible and can not be guaranteed in the long-term.

- Although some work has been done to help determine the source of groundwater at GQSoE monitoring bores, the age of this water and its recharge areas are generally unknown. This has been identified as a major knowledge gap across New Zealand (eg, Daughney & Randall 2009) and makes it difficult to identify and understand relationships between land use and groundwater quality. As a result, it is often difficult to understand the impacts of some consented activities on groundwater (and, subsequently surface water).

- Although many areas of surface and groundwater interaction are known across the region, it would be useful to try and estimate the proportion of flow that groundwater may contribute to surface water in specific surface water bodies, particularly in areas where groundwater nitrate concentrations are highly elevated (>7 mg/L).

- There is limited knowledge of the presence of emerging contaminants (eg, detergents and pharmaceuticals) in groundwater in the Wellington region.

7. Conclusions

Median values drawn from GQSoE data collected quarterly between August 2005 and July 2010 indicate that groundwater quality in the Wellington region is generally very good, particularly from a drinking water perspective. Iron and manganese were the main two variables to exceed DWSNZ (2005) thresholds, but these exceedences were generally limited to non-potable bores located in semi-confined to confined oxygen-poor aquifers that naturally exhibit elevated concentrations of these elements. Positive *E. coli* counts were recorded on at least one sampling occasion in 26 bores, six of which are used for potable supply. Some of this contamination may reflect poor borehead protection rather than the quality of the underlying groundwater quality. However, one bore at Te Horo Beach on the Kapiti Coast consistently recorded *E. coli* counts well in excess of the DWSNZ (2005) MAV and water quality in this bore is clearly impacted by land use at the site.

Surveys undertaken in 2006 and 2010 indicate there is limited pesticide and herbicide contamination of groundwater in the Wellington region. Similarly, a one-off assessment of heavy metals and metalloids in March 2009 found no significant contamination issues other than identifying a relatively widespread presence of arsenic which is consistent with natural rock-water interaction.

Temporal trend analyses performed across 10 water quality variables revealed a relatively small proportion (7.6%) of environmentally meaningful trends (ie, statistically significant and a relative rate of change >5%/year, or an absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr). The majority of these trends were associated with just four variables: dissolved manganese (11), dissolved iron (8), dissolved reactive phosphorus (DRP, 9) and nitrate nitrogen (8). Further, over half (58%) of the environmentally meaningful trends reflected decreases in the concentration of a specific water quality variable and, therefore, can be considered representative of improving trends.

While the Drinking Water Quality Index (WQI) classified 75% of the 71 GQSoE bores as being ‘good’ or ‘excellent’ for potable use, the Aquatic Ecosystems WQI showed that just 49% of the bores were ‘good’ or ‘excellent’, a reflection of the lower thresholds used to assess aquatic toxicity, particularly for nitrate nitrogen (nitrate) and zinc. In the case of nitrate, none of the 71 GQSoE bores recorded a median concentration above the DWSNZ (2005) MAV but, in 23 bores, the median exceeded the recommended aquatic ecosystems toxicity threshold of 1.7 mg/L. Of these 23 bores, 17 are located in unconfined to semi-confined aquifers where there is an increased likelihood of discharge to surface water. While strong evidence exists that discharge of nitrate-enriched groundwater is impacting on surface water quality in the Mangatarere and Parkvale Stream catchments near Carterton, potential impacts from nitrate-enriched groundwater discharge in other catchments in the Wellington region are largely unknown. With further land use intensification expected in the region in the future (eg, in some parts of the Wairarapa) and long time lags often associated with groundwater entering surface water, it is critical that best practice land management practices are implemented to minimise adverse impacts on underlying groundwater and connected surface water resources. Continued monitoring of soil, groundwater and surface water quality is also needed.

7.1 Recommendations

1. Review the appropriateness of the existing suite of GQSoE monitoring bores, taking into account surface water hydrology and quality considerations, as well as bore/well head security, source capture zone information (where available) and aquifer confinement.

2. Undertake, in addition to quarterly monitoring for the routine suite of physico-chemical variables, periodic screening of GQSoE bores for the presence of pesticides, heavy metals and emerging contaminants.

3. Continue to gather information on groundwater age and source for GQSoE monitoring bores.

4. In the next five-yearly assessment of temporal trends in groundwater quality, consider using the same starting date as used in this report (August 2005) to increase the robustness of trend analysis.

5. Take into account the findings of this report in the review of Greater Wellington's existing regional plans, particularly the need for nutrient budgeting to minimise nutrient losses from agricultural and horticultural land uses.

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Appendix 1: GQSoE monitoring sites and programme changes

Table A1.1: GQSoE monitoring site details

Bore no.	NZMG (1949)		NZTM		Depth (m)	Aquifer confinement	Bore use	Date joined the GQSoE network	HCA sub-cluster
	Easting	Northing	Easting	Northing					
Kapiti Coast									
R25/5100	2684570	6041166	1774552.15	5479451.35	48.20	Semi-confined	Irrigation	1993	B1a
R25/5135	2689170	6043198	1779152.45	5481483.39	93.27	Confined	Irrigation	1993	B2a
R25/5164	2685891	6044082	1775873.28	5482367.50	0.00	Unconfined	Domestic	1997	A1a
R25/5165	2686037	6043601	1776019.28	5481886.47	8.00	Unconfined	Domestic	1998	B1a
R25/5190	2686696	6040703	1776678.23	5478988.27	0.00	Unconfined	Potable domestic and stock	1999	A2a
R25/5233	2689415	6049279	1779397.56	5487564.84	18.70	Semi-confined	Dairy Use	1996	A1b
R26/6503	2676272	6024010	1766253.09	5462295.15	14.80	Unconfined	Irrigation	1995	A2a
R26/6587	2682652	6034772	1772633.83	5473057.09	12.96	Unconfined	Irrigation	1993	A1b
R26/6624	2683951	6036012	1773932.93	5474297.10	10.20	Confined	Irrigation	1996	A2a
S25/5125	2692751	6044728	1782733.73	5483013.44	10.00	Unconfined	Irrigation	1996	A1b
S25/5200	2691200	6041500	1781182.52	5479785.21	45.80	Semi-confined	Irrigation	1993	B1a
S25/5256	2690508	6044868	1780490.58	5483153.49	30.78	Confined	Irrigation	1993	A2a
S25/5322	2693000	6049200	1782982.85	5487485.83	27.00	Semi-confined	Irrigation	1993	A2a
Hutt Valley									
R27/0320	2667018	5996221	1756996.50	5434507.51	114.6	Confined	Fire	1993	B1b
R27/1137	2683427	6006672	1773406.32	5444956.34	20.40	Unconfined	Industrial	1996	A1c
R27/1171	2666515	5992940	1756493.07	5431226.71	23.20	Confined	Water level observation	1993	B1b
R27/1180	2670457	5997412	1760435.48	5435698.05	39.00	Confined	Public	1993	A1b
R27/1182	2669296	5993875	1759274.04	5432161.32	38.00	Confined	Groundwater quality	1993	A2a
R27/1183	2673105	6000405	1763083.77	5438690.64	25.00	Confined	Air conditioning	1993	A1c
R27/1265	2667019	5996229	1756997.50	5434515.51	48.30	Confined	Fire	1993	A1b
R27/6833	2687737	6007040	1777716.35	5445323.81	24.50	Semi-confined	Potable and domestic	1996	A1b
Wainuiomata									
R27/6418	2672241	5987409	1762217.86	5425695.18	8.00	Unconfined	Irrigation	1996	A1b
Wairarapa Valley									
S26/0117	2721500	6018500	1811483.15	5456780.11	5.00	Unconfined	Potable and domestic	2005	A1b
S26/0223	2726219	6021005	1816203.19	5459284.79	9.92	Unconfined	Potable and domestic	2004	A1b
S26/0299	2728370	6023590	1818354.91	5461869.91	8.10	Unconfined	Potable and domestic	1997	A1c
S26/0439	2717510	6016900	1807492.42	5455180.48	11.50	Unconfined	Stock	2005	A1b
S26/0457	2717675	6012051	1807656.62	5450330.89	6.06	Unconfined	Potable, domestic and irrigation	1998	A1c
S26/0467	2719290	6015570	1809272.40	5453850.06	6.20	Unconfined	Potable and domestic	2005	A1b
S26/0568	2723504	6013642	1813486.57	5451921.15	45.00	Confined	Irrigation	1998	B1b
S26/0576	2723479	6014255	1813461.67	5452534.23	31.00	Confined	Irrigation	1998	B1b
S26/0705	2720489	6015999	1810471.61	5454278.93	27.40	Confined	Public	1997	A1b
S26/0756	2725937	6010018	1815919.19	5448296.24	19.00	Confined	Irrigation	1998	B1a
S26/0762	2725720	6011070	1815702.37	5449348.42	9.50	Confined	Domestic and stock	1998	B2a
S26/0824	2720564	6016101	1810546.63	5454380.93	20.60	Confined	Public	1997	A1b

Bore no.	NZMG (1949)		NZTM		Depth (m)	Aquifer confinement	Bore use	Date joined the GQSoE network	HCA sub-cluster
	Easting	Northing	Easting	Northing					
S26/0846	2717921	6011212	1807902.50	5449491.76	39.30	Confined	Not used	2005	A1c
S27/0009	2703916	6005200	1793895.42	5443481.45	10.50	Unconfined	Domestic	2005	A1b
S27/0070	2707528	6004830	1797507.54	5443110.86	14.60	Unconfined	Public	2005	A1c
S27/0136	2712237	6008109	1802217.44	5446389.36	20.40	Unconfined	Potable, domestic and irrigation	2005	A1b
S27/0156	2713423	6004496	1803402.88	5442775.85	20.70	Semi-confined	Irrigation	2005	B1b
S27/0202	2715480	6008240	1805460.73	5446519.85	4.80	Unconfined	Irrigation	1997	A1b
S27/0268	2703475	5995774	1793452.70	5434055.07	58.40	Confined	Irrigation and stock	1998	B2b
S27/0283	2707298	5997888	1797276.24	5436168.48	19.00	Confined	Irrigation	1998	B2a
S27/0299	2706525	6000655	1796503.73	5438935.77	17.40	Confined	Irrigation	1998	A1c
S27/0344	2713369	5999061	1803347.81	5437340.43	16.00	Confined	Irrigation	1998	B1a
S27/0389	2717227	5995514	1807205.35	5433792.40	17.85	Confined	Irrigation	2003	B1b
S27/0396	2715880	5997683	1805858.70	5435961.84	17.00	Confined	Public	1997	A2b
S27/0433	2697716	5989557	1787692.45	5427838.97	44.60	Confined	Irrigation	1998	B2b
S27/0435	2697631	5992523	1787608.01	5430805.03	44.00	Confined	Stock	1998	B2a
S27/0442	2699915	5988602	1789891.27	5426883.54	177.7	Confined	Potable domestic and stock	2005	B2a
S27/0495	2707250	5993050	1797227.31	5431330.26	37.50	Confined	Irrigation	1998	B2a
S27/0522	2713054	5993045	1803031.58	5431324.10	21.00	Confined	Potable and domestic	2004	A2b
S27/0571	2717180	5994736	1807158.18	5433014.36	32.00	Confined	Irrigation	2004	A2a
S27/0585	2690345	5984315	1780320.53	5422598.32	42.00	Confined	Irrigation	1998	B2a
S27/0588	2694869	5982431	1784844.06	5420713.48	11.70	Confined	Public	1997	B1a
S27/0594	2691376	5981438	1781350.93	5419721.16	44.00	Confined	Irrigation	1998	B2a
S27/0602	2699650	5987020	1789625.95	5425301.57	60.95	Confined	Irrigation	1998	B2a
S27/0607	2696313	5986755	1786288.91	5425037.20	38.00	Confined	Irrigation	1998	B2b
S27/0614	2696803	5983642	1786778.28	5421924.10	35.80	Confined	Irrigation	1998	B1a
S27/0615	2696830	5983876	1786805.33	5422158.09	18.20	Confined	Irrigation	1998	B1a
S27/0681	2718974	5995264	1808952.42	5433542.02	5.00	Unconfined	Irrigation	2004	A2b
T26/0003	2732572	6034955	1822559.22	5473236.52	5.50	Unconfined	Potable and domestic	2004	A1c
T26/0087	2730310	6026470	1820295.66	5464750.15	36.00	Semi-confined	Potable domestic and stock	2004	A1c
T26/0099	2732532	6029339	1822518.46	5467619.40	15.00	Unconfined	Potable and domestic	2004	A1b
T26/0206	2732595	6029549	1822581.50	5467829.43	28.70	Unconfined	Irrigation	2004	A1b
T26/0259	2736010	6030840	1825997.33	5469120.23	6.10	Unconfined	Public	1997	A1c
T26/0332	2732246	6019123	1822230.80	5457401.54	13.40	Semi-confined	Domestic and stock	2004	A1b
T26/0413	2734500	6021700	1824485.62	5459978.64	23.30	Confined	Potable, domestic and irrigation	2004	B1b
T26/0430	2732145	6024748	1822130.71	5463027.57	0.00	Unconfined	Potable and stock	1997	A1c
T26/0489	2737585	6023576	1827571.49	5461854.50	54.00	Semi-confined	Irrigation	1997	A2a
T26/0538	2737752	6022891	1827738.41	5461169.34	9.00	Unconfined	Not used	1997	A2a
Riversdale (Eastern Wairarapa)									
T27/0063	2768035	6008362	1858025.04	5446630.37	3.59	Unconfined	Groundwater quality	2006	A2b

Site selection information and key site/programme changes

The existing GQSoE monitoring programme consists of 71 bores. The criteria for selecting the location of these bores included:

- *Groundwater use* – aquifers used for potable water supply and/or aquifers with allocation greater than 30% of the estimated safe yield;
- *Groundwater quality* – aquifers identified as having potentially degraded water quality, such as elevated nitrate or bacteriological levels; and
- *Spatial integrity* – all identified groundwater zones and, where practical, all aquifers in these zones, were included to ensure good spatial coverage.

Once the bore location was determined, individual site suitability was assessed using the following criteria:

- The sampling site is representative of the groundwater zone and aquifer to be monitored;
- The bore or well construction details are known, especially the well screen setting;
- A bore log is available for the monitoring bore;
- The well head is secure;
- The well or bore is accessible;
- The well or bore is not susceptible to point source contamination; and
- The well or bore is in regular use.

Data have been collected under the GQSoE monitoring programme at some sites since 1994. Prior to 2006, samples were collected in accordance with protocols outlined in the national guidelines for the collection of groundwater samples for chemical and isotopic analyses (Rosen et. al 1999). However, it is unclear if these protocols were implemented from the commencement of the monitoring programme, and in both the western and eastern (Wairarapa) parts of the region. Post-2006, all groundwater samples have been collected in accordance with nationally accepted protocols (Ministry for the Environment 2006).

Prior to 2003, calcium, sodium, potassium, magnesium, manganese, boron, lead, zinc and iron were analysed and reported as total concentrations, and the frequency of groundwater sampling varied from biannually to quarterly to adhoc. The decision to switch from biannual to quarterly sampling to improve detection of long-term trends and seasonal variation was made in October 2003. However, groundwater samples were not consistently collected within the months of March, June, September and December until 2007.

Between 2004 and 2005, 18 new bores were added to the GQSoE monitoring network. The site network has remained relatively stable since 2005, with just two changes:

- Bores S26/0400 (Fitzgerald) and S27/0547 (Campbell) were dropped from the network in January 2005 and September 2006, respectively; and
- Bore T27/0063 (Acacia Ave) was added to the network in September 2006.

Appendix 2: Water quality variables and analytical methods

Groundwater samples are collected at quarterly intervals by trained Greater Wellington staff using nationally accepted protocols (Ministry for the Environment 2006). This involves purging the bore for a predetermined amount of time to remove any standing water and monitoring the pumped water continuously until field measurements (eg, conductivity) stabilise. These practices are employed to make sure that the water sampled is representative of the aquifer. Field measurements (temperature, conductivity, pH and dissolved oxygen) are taken using field meters calibrated on the day of sampling. Water samples are stored on ice upon collection and transported to an external laboratory within 24 hours of sampling. The variables monitored are outlined in Table A2.1 and the current analytical methods are summarised in Table A2.2.

With the exception of *E. coli* and faecal coliform tests between 2003 and September 2009 (performed by BioStandards Laboratory and later Environmental Laboratory Services), all tests listed in Table A2.2 are performed by RJ Hill Laboratories in Hamilton.

Table A2.1: Core physico-chemical and microbiological water quality variables in Greater Wellington's GQSoE monitoring programme

Variable type	Variable	Explanation
Bacteria	Faecal coliforms *Escherichia coli* (*E. coli*)	Faecal coliforms *and E. coli* can indicate pollution due to faecal matter and the presence of potentially harmful pathogens in groundwater. The Ministry for the Environment uses *E. coli* as a national indicator of groundwater quality.
Major ions	Dissolved sodium Dissolved potassium Dissolved calcium Dissolved magnesium Chloride Sulphate Total alkalinity	Concentrations of major ions can give an indication of the chemical composition of the water, the origins of groundwater, water residence time in the aquifer and the extent of rock/water interaction. Concentrations of major ions can also be indicative of groundwater contamination from industrial, agricultural and domestic sources.
Nutrients	Ammoniacal nitrogen Nitrite-nitrate nitrogen (NNN) Nitrate nitrogen Nitrite nitrogen Dissolved reactive phosphorus	Dissolved concentrations of nutrients can indicate impact from anthropogenic activity such as intensive land use. Nitrate nitrogen represents the oxidised form of nitrogen. Elevated concentrations of nitrate nitrogen can have an adverse effect on human health and can be harmful to aquatic life. Nitrate nitrogen is a national indicator of groundwater quality. Ammoniacal nitrogen usually exists under oxygen-poor conditions and represents the reduced form of nitrogen. Therefore, ammonical nitrogen can be used as an indicator of contamination in the absence of nitrate nitrogen.
Metals	Dissolved iron Dissolved manganese Dissolved lead Dissolved zinc	Trace metals are usually present in groundwater at low concentrations – elevated concentrations can suggest contamination of groundwater. Elevated concentrations of dissolved lead and manganese can adversely affect human health.

Table A2.1 *cont*.: Core physico-chemical and microbiological water quality variables in Greater Wellington's GQSoE monitoring programme

Trace elements	Bromide Fluoride Dissolved boron	Bromide naturally occurs in water but can suggest contamination from wastewater and agricultural run off. The DWSNZ (2005) MAV for fluoride is set to protect against potential dental fluorosis. Elevated concentrations of dissolved boron can have adversely affect human health.
Other	pH	Water with a low pH can have a high plumbosolvency. It is measured in the field to identify when the bore is purged and water samples can be collected for analysis.
	Electrical conductivity	Electrical conductivity can provide a measure of total dissolved solids. Measured in the field to identify when the bore is purged and water samples can be collected for analysis.
	Dissolved oxygen	Dissolved oxygen (DO) can indicate whether groundwater is under reduced or oxidised conditions. DO is measured in the field to identify when the bore is purged and water samples can be collected for analysis.
	Dissolved reactive silica	Can help interpret the extent of rock/water interaction.
	Total organic carbon (TOC)	Can indicate the presence of organic matter (either from wastewater or natural sources) in groundwater.
Calculations	Total dissolved solids (TDS)	Can indicate the extent of rock/water interaction.
	Free carbon dioxide (CO_2)	Can indicate the extent of rock/water interaction.
	Bicarbonate (H_2CO_3)	Can indicate the extent of rock/water interaction.
	Total hardness	Can indicate the extent of rock/water interaction.
	Total anions	Sum of all anions
	Total cations	Sum of all cations
	% Difference in ion balance	Difference between the sum of all anions and the sum of all cations. Can be used as a measure of analytical accuracy of water quality data. Value should be 0% but generally a difference of <5% is considered acceptable.

N.B: Groundwater samples are also tested for arsenic, chromium, cadmium, nickel and copper but on a not routine basis. Conductivity and pH are measured in both the field and the laboratory. Dissolved oxygen is only measured in the field – see Table A2.2.

Table A2.2: GQSoE analytical methods and detection limits

Variable	Method	Detection limit
Temperature	Field meter –YSI 556 , WTW P4 Multiline and WTW350i Meters	0.01°C
Dissolved oxygen	Field meter –YSI 556 , WTW P4 Multiline and WTW350i Meters	0.01 mg/L
Electrical conductivity	Field meter –YSI 556 , WTW P4 Multiline and WTW350i Meters	0.1 µS/cm
pH	Field meter – YSI 556 , WTW P4 Multiline and WTW350i Meters	0.01 units
pH (lab)	pH meter APHA 4500-H+ B 21st Ed. 2005.	0.1 pH units
Total alkalinity	Titration to pH 4.5 (M-alkalinity), Radiometer autotitrator. APHA 2320 B (Modified for alk <20) 21st Ed. 2005.	1 mg/L as $CaCO_3$
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO2 D 21st Ed. 2005.	1 mg/L at 25°C
Free carbon dioxide		1 mg/L at 25°C
Total hardness	Calculation from calcium and magnesium	1 mg/L $CaCO_3$
Electrical conductivity (lab)	Conductivity meter, 25°C APHA 2510 B 21st Ed. 2005.	0.1 mS/m, 1 µS/cm
Total dissolved solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103–105°C used rather than 180 ± 2°C) 21st Ed. 2005.	10 mg/L
Dissolved boron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st Ed. 2005.	0.005 mg/L
Dissolved calcium	Filtered sample, ICP-MS APHA 3125 B 21st Ed. 2005.	0.05 mg/L
Dissolved iron	Filtered sample. ICP-MS APHA 3125 B 21st Ed. 2005.	0.02 mg/L
Dissolved lead	Filtered sample. ICP-MS APHA 3125 B 21st Ed. 2005.	0.0001 mg/L
Dissolved magnesium	Filtered sample, ICP-MS APHA 3125 B 21st Ed. 2005.	0.02 mg/L
Dissolved manganese	Filtered sample. ICP-MS APHA 3125 B 21st Ed. 2005.	0.0005 mg/L
Dissolved potassium	Filtered sample, ICP-MS APHA 3125 B 21st Ed. 2005.	0.05 mg/L
Dissolved sodium	Filtered sample, ICP-MS APHA 3125 B 21st Ed. 2005.	0.02 mg/L
Dissolved zinc	Filtered sample. ICP-MS APHA 3125 B 21st Ed. 2005.	0.001 mg/L
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st Ed. 2005.	0.05 mg/L
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 21st Ed. 2005.	0.5 mg/L
Fluoride	Ion selective electrode APHA 4500-F- C 21st Ed. 2005.	0.05 mg/L
Total ammoniacal nitrogen	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N=NH_4+-N + NH_3-N) APHA 4500-NH_3 F (modified from manual analysis) 21st Ed. 2005.	0.01 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3 - I (modified) 21st Ed. 2005.	0.002 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) – Nitrite-N.	0.002 mg/L
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3 - I (modified) 21st Ed. 2005.	0.002 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st Ed. 2005.	0.004 mg/L
Reactive silica	Filtered sample. Heteropoly blue colorimetry. Discrete Analyser. APHA 4500-SiO_2 F (modified from flow injection analysis) 21st Ed. 2005.	0.1 mg/L as SiO_2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st Ed. 2005.	0.5 mg/L
Total organic carbon (TOC)	Catalytic oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 B (modified) 21st Ed. 2005.	0.05 mg/L
Total anions	Calculation: sum of anions as mEquiv/L [Includes Alk, Cl, NO_xN & SO_4]	0.07 mEquiv/L
Total cations	Calculation: sum of cations as mEquiv/L [Includes Ca, Mg, Na, K, Fe, Mn, Zn & NH_4N].	0.06 mEquiv/L
Faecal coliforms	APHA 21st Ed. Method 9222 D.	1 cfu/100mL
E. coli	APHA 21st Ed. Method 9222 G.	1 cfu/100mL

Appendix 3: Hydrochemistry multivariate statistics

Mulitvariate statistical methods employed in Section 4.1 of this report are outlined below, based largely on material in Daughney (2010).

Principal components analysis (PCA)

PCA is a mathematical manipulation that reduces the dimensionality of a data set. For this report, PCA was conducted with log-transformed (to the base 10) values of 15 variables (bromide, calcium, chloride, fluoride, iron, bicarbonate, potassium, magnesium, manganese, sodium, ammonia, nitrate, DRP, silica and sulphate) routinely monitored in the GQSoE network between 1 August 2005 to 31 July 2010. The results of PCA are displayed by visualisation of the principal component weightings on two-dimensional bi-plots (Figure A3.1).

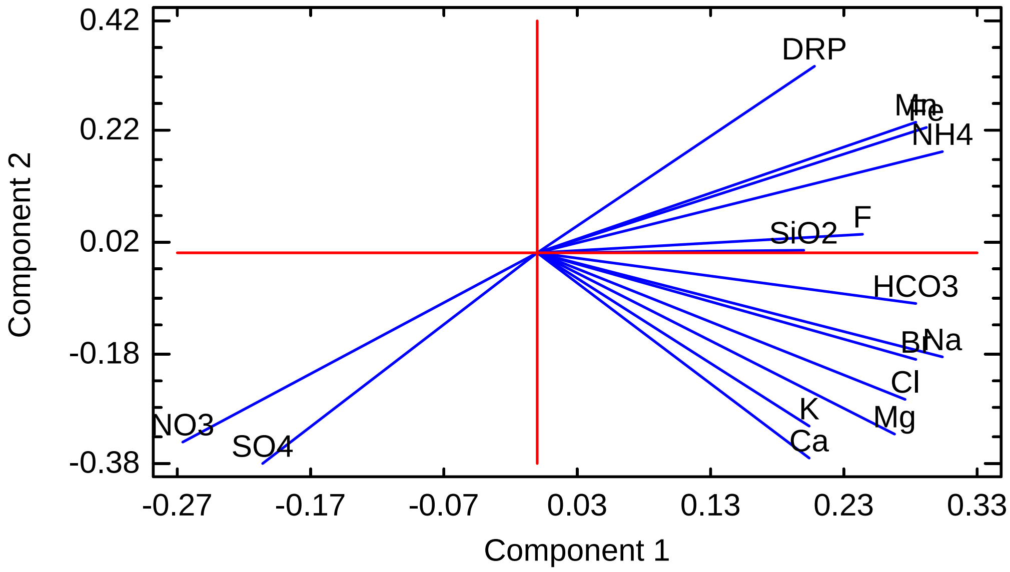


Figure A3.1: Example bi-plot of principal component weightings derived from GQSoE data collected quarterly between August 2005 and July 2010. Components 1 and 2 both show negative weightings of nitrate nitrogen and sulphate and positive weightings of ammoniacal nitrogen, iron and manganese, indicating that high concentrations of nitrate nitrogen tend to occur with low concentrations of ammoniacal nitrogen, iron and manganese. Component 1 also shows positive weightings of all variables except nitrate nitrogen and sulphate, which shows that higher TDS is typically associated with low concentrations of nitrate nitrogen and sulphate. Component 2 shows variable weightings indicative of major cation and anion ratio (ie, water type): Calcium and sodium show strong negative loadings, indicating the water type is calcium and sodium dominated.

Hierarchical cluster analysis (HCA)

HCA can be used to define water quality ‘clusters’ (ie, groups or categories) and assign monitoring sites to these clusters on the basis of water quality. HCA has also been applied to data collected through the National Groundwater Monitoring Programme (NGMP), to understand spatial variations in groundwater hydrochemistry across all of New Zealand (Daughney & Reeves 2005; 2006). HCA is performed purely on the basis of water chemistry and does not explicitly consider any factors such as site location, catchment lithology or land use. Thus HCA can potentially provide a simple summary of the variation in water chemistry across Greater Wellington’s entire GQSoE network without any prior assumptions about which parts of the Wellington region might be dominated by particular water quality categories (Daughney 2010).

In this report, HCA was conducted with log-transformed (to the base 10) values of 15 variables (bromide, calcium, chloride, fluoride, iron, bicarbonate, potassium, magnesium, manganese, sodium, ammonia, nitrate, DRP, silica and sulphate) routinely monitored in the GQSoE network between August 2005 and July 2010.

HCA was conducted using two categorisation methods. First, HCA was conducted using the Nearest Neighbour linkage rule. The Nearest Neighbour method identifies samples that have unusual chemistry compared to the other samples in the data set (these unusual samples are termed 'residuals') and which should be excluded from further analysis due to their possible biasing influence. Second, HCA was conducted using Ward's linkage rule, after the exclusion of samples identified as residuals. Ward's method is typically the most appropriate for hydrochemical assessments (Güler et al. 2002), because it generates clusters in which observations (ie, individual samples) are most similar to one another but most dissimilar to observations from other clusters (Daughney 2010).

Results from HCA are presented in four ways. First, a 'membership list' is produced in which each site is assigned to one of several clusters. Second, the cluster assignments can be displayed in map form. Third, results of HCA are presented in terms of cluster 'centroids', where a centroid for a particular cluster gives the median value of each variable considered in the HCA algorithm. Fourth, HCA results are displayed graphically in the form of a dendrogram (Daughney 2010) (Figure A3.2).

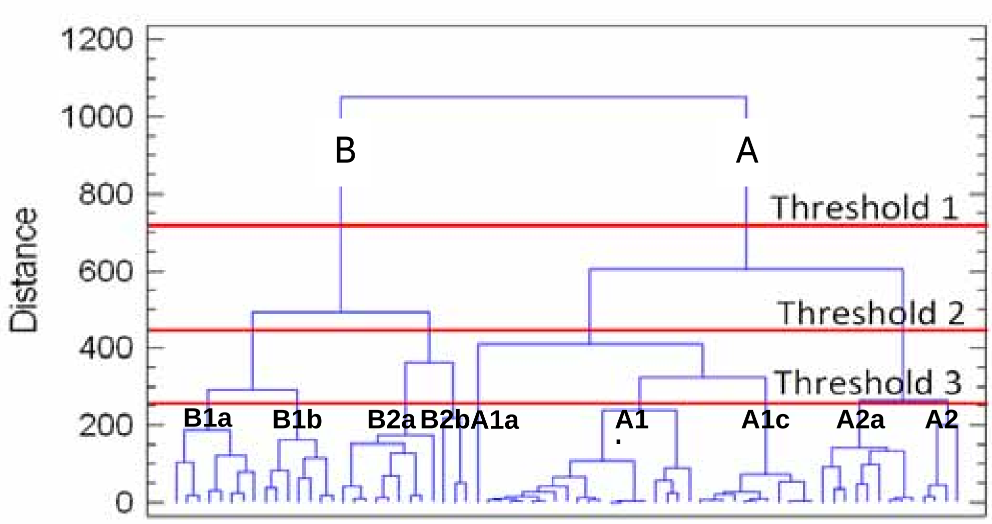


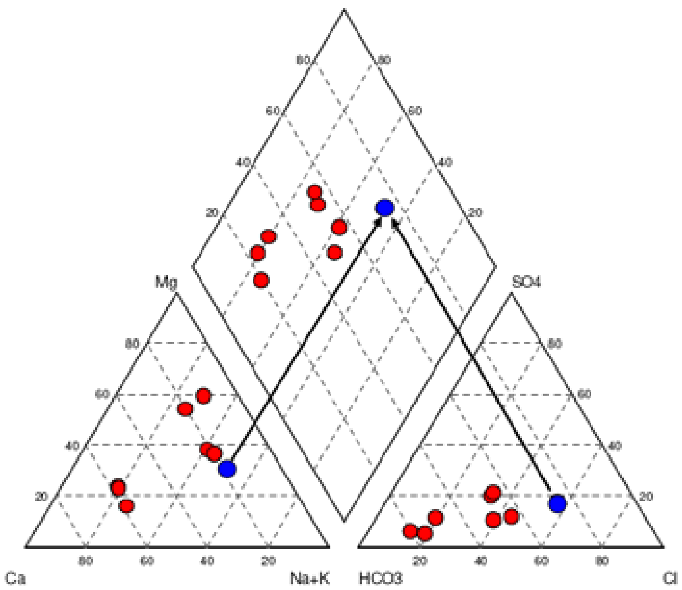
Figure A3.2: Dendrogram displaying the level of dissimilarity in hydrochemistry at all GQSoE bores. This dendrogram is based on the Ward's method, using median results (log transformed to the base ten) from 15 selected variables measured quarterly in the GQSoE monitoring programme between August 2005 and July 2010. The terminus of each vertical line represents a single water quality monitoring site. The *y*-axis is a dissimilarity measure: sites or groups of sites are joined together by horizontal lines, and the position of any horizontal line indicates how similar (small values on the *y*-axis) or dissimilar (large values on the *y*-axis) the sites or groups it joins actually are. The lowest red line represents a separation threshold at which the sites are partitioned into nine distinct clusters. A higher value for the separation threshold would result in recognition of fewer clusters, whereas a lower value would result in definition of more clusters.

Piper diagram

The Piper diagram is a graphical method that is used to display ionic ratios for water quality data (Freeze & Cherry 1979). Most commonly, the diagram is used to depict the relative concentrations of the major cations (Ca vs Mg vs Na+K) and anions (HCO_3 vs Cl vs SO_4) on two separate triangular plots, with a central diamond plot onto which points from the two triangular plots are projected (Figure A5.3). The position of any point in the central diamond is used to determine the 'water type' of the sample, which can be used to make inferences about its origin and chemical evolution (Daughney 2010).

In this report, a Piper diagram (created in AquaChem, Version 3.7) was used to graphically represent the water chemistry at each GQSoE bore using the median results for seven major anions and cations tested as part of the GQSoE monitoring programme between August 2005 and July 2010: calcium magnesium, sodium, potassium, bicarbonate, chloride and sulphate.

The water type defined from a Piper diagram is not necessarily related in a straightforward manner to the clusters defined by HCA, even when the two methods are based on the same major ion concentrations. Note also that Piper diagrams are principally used to display only the *ratios* of concentrations of major ions. For example, rain water and seawater are strongly differentiated by ion concentrations and TDS, but both are Na-Cl type waters and hence would plot essentially on top of each other on a Piper diagram. Thus it is often useful to display absolute concentrations on a Piper diagram by using symbols of different size, shape or colour – but the number of variables that can be displayed in an interpretable manner on a single diagram is very limited. It is therefore important to interpret Piper diagrams with the aid of complementary methods such as box-and-whisker plots (Daughney 2010).



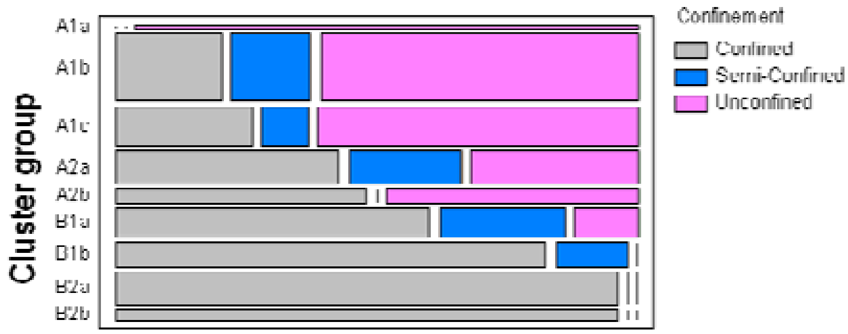
(Source: Daughney (2010))

Figure A3.3: Example Piper diagram showing major ion ratios for eight different water samples. All three blue points pertain to a single sample, with the left and right triangular plots showing the major cation and anion ratios respectively, and the centre diamond plot showing the projected position based on the two triangular plots. The sample represented by the blue symbol has Na (or K) as the dominant cation and Cl as the dominant anion and would therefore be classed as a Na-Cl water type.

Cross-tabulation

Cross-tabulation analysis, also known as contingency table analysis, is used to analyse categorical (nominal measurement scale) data, for example to detect relationships between aquifer location or aquifer confinement categories and the clusters defined by HCA. A cross-tabulation is a two (or more) dimensional table or figure that counts the number of times each unique value occurs in the first variable, then in the second, and so on. The Chi-square test can be used to assess the statistical significance of the cross-tabulation, that is, to determine if the categorical variables being compared are related or independent (Daughney 2010; Helsel & Hirsch 1992).

The vertical thickness of each row is proportional to the percentage of sites assigned to each unique sub-category (Figure A3.4). The area of each rectangle is proportional to the number of sites at each location or within aquifer confinement types (colours are arbitrary) (Daughney 2010).



Tests of Independence

Test	Statistic	Df	P-Value
Chi-Squared	32.152	16	0.0096

Warning: some expected cell counts < 5.

Figure A3.4: Cross-tabulation plot showing relationship between the nine GQSoE sub-clusters defined by HCA and aquifer confinement. A Chi-square test confirmed the relationship is statistically significant ($p<0.05$).

Box-and-whisker plots

Box-and-whisker (box) plots are used to evaluate differences in the value of a certain variable between several different groups (Helsel & Hirsch 1992). In Section 4.1.4 of this report box plots (generated using Stratigraphic Centurion, Version 15) were used to evaluate the difference in a variables such as calcium concentration, TDS, etc. between different sub-clusters identified by HCA. These plots (Figure A3.5) were based on GQSoE data (for the 15 variables used in the multivariate analyses and seven additional variables used to aid interpretation of the multivariate analyses). See Section 4.2.1(a) for information on interpreting the box plots.

Figure A3.5: Box plots displaying median results for 22 water quality variables from 71 GQSoE bores sampled quarterly between 1 August 2005 and 31 July 2010, with GQSoE bores grouped according to their hydrochemistry

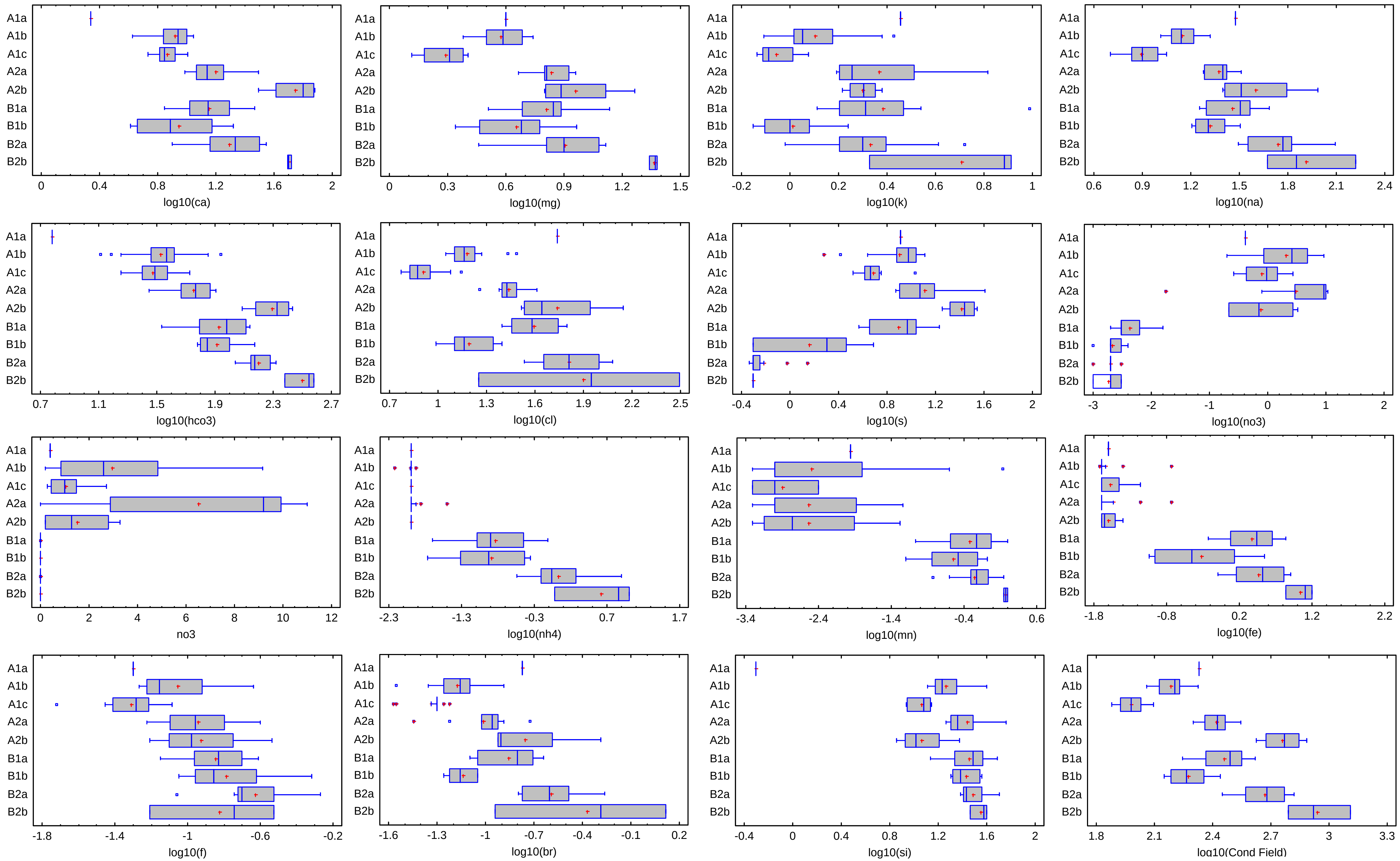
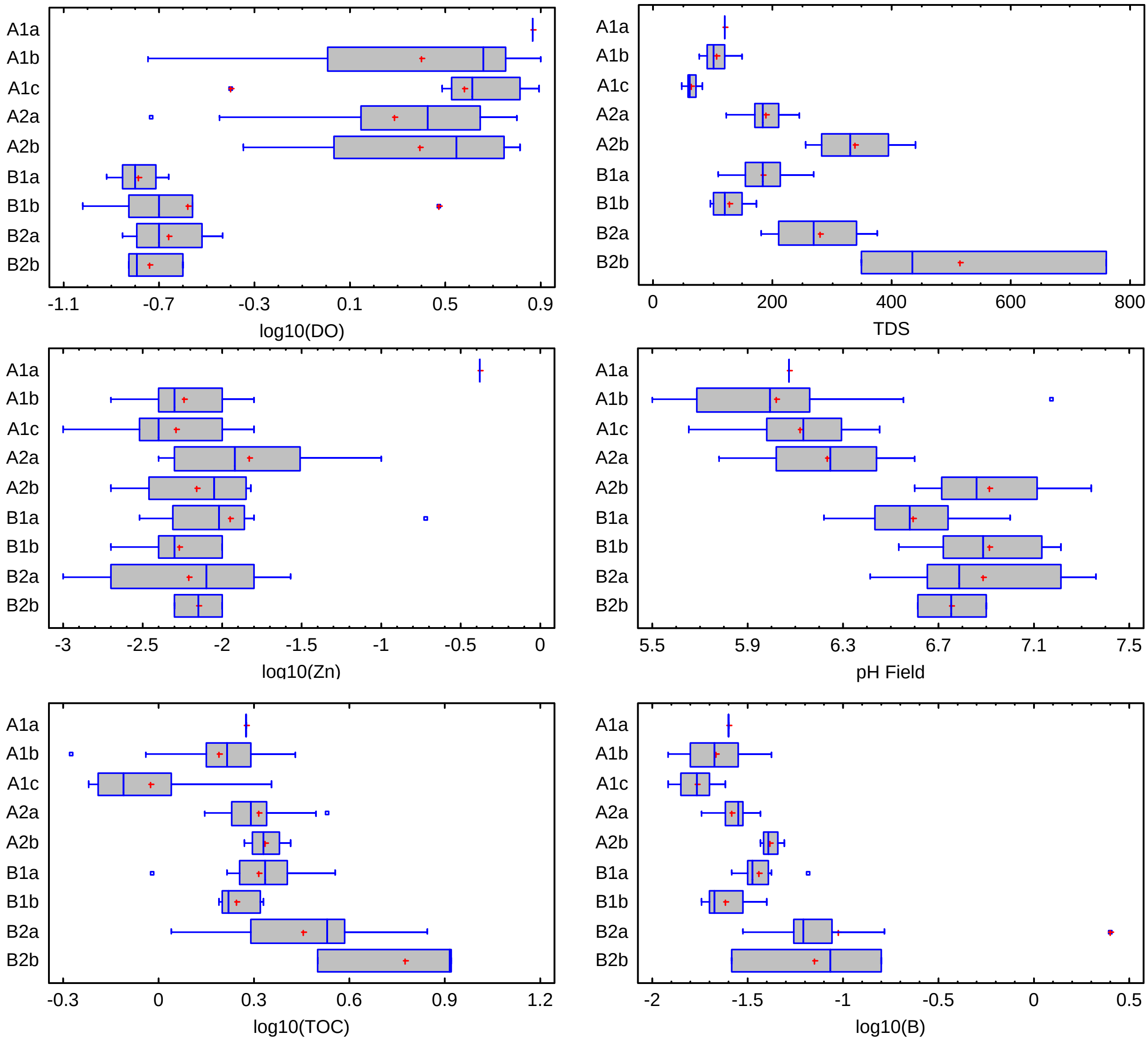


Figure A3.5 *cont.:* Box plots displaying median results for 22 water quality variables from 71 GQSoE bores sampled quarterly between 1 August 2005 and 31 July 2010, with GQSoE bores grouped according to their hydrochemistry



Appendix 4: Summary statistics – groundwater quality

Table A4.1: Median concentrations (and range as 5th and 95th percentiles) of 22 variables measured quarterly in 71 GQSoE bores in the Wellington region over the period 1 August 2005 to 31 July 2010. The values presented have been determined employing the NADA approach as outlined in Section 4.2.1(a).

Site no.	Water temperature (°C)					pH					Conductivity (µS/cm)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	14.3	13.2	15.2	0	20	7.0	6.8	7.5	0	17	337.0	271.8	364.0	0	19
R25/5135	14.4	14.1	14.6	0	18	7.2	6.9	7.5	0	16	590.0	511.0	612.8	0	17
R25/5164	14.2	9.1	19.0	0	19	6.1	5.6	7.1	0	16	214.0	121.6	313.5	0	18
R25/5165	14.9	14.6	15.6	0	19	6.7	6.4	7.0	0	16	175.0	110.8	242.8	0	17
R25/5190	15.6	15.2	17.3	0	20	6.6	6.4	6.9	0	17	267.0	209.1	336.2	0	19
R25/5233	14.9	14.3	15.5	0	20	6.0	5.8	7.6	0	16	147.0	119.8	240.4	0	19
R26/6503	14.4	14.0	14.7	0	20	6.4	6.3	6.9	0	17	265.0	239.8	295.2	0	19
R26/6587	14.5	14.2	15.0	0	17	6.1	5.9	6.3	0	15	131.5	112.3	152.5	0	16
R26/6624	14.9	14.2	15.6	0	19	6.2	6.0	6.8	0	16	227.0	189.6	247.4	0	18
S25/5125	14.5	13.3	16.4	0	21	5.8	5.6	6.0	0	18	130.0	108.4	185.1	0	20
S25/5200	14.2	13.7	15.1	0	18	6.5	6.3	6.8	0	15	277.0	246.0	289.2	0	17
S25/5256	14.7	14.3	15.0	0	19	5.9	5.7	6.6	0	16	229.5	207.3	247.3	0	18
S25/5322	14.5	14.2	15.7	0	21	6.4	6.2	6.8	0	18	318.0	281.2	333.3	0	20
Hutt Valley															
R27/0320	14.2	13.0	15.7	0	20	7.2	6.8	7.4	0	17	185.0	166.2	192.0	0	19
R27/1137	14.8	14.0	22.0	0	20	6.0	5.7	6.7	0	18	109.0	86.4	129.2	0	19
R27/1171	13.3	11.6	16.5	0	14	6.5	5.9	7.2	0	11	153.0	106.3	155.4	0	12
R27/1180	14.3	14.0	15.5	0	20	5.9	5.8	6.4	0	18	135.0	122.5	150.9	0	19
R27/1182	14.5	14.4	15.0	0	19	6.2	6.0	6.5	0	18	198.5	189.5	204.8	0	18
R27/1183	13.9	12.4	16.2	0	20	6.3	5.8	6.4	0	17	96.0	86.6	115.4	0	19
R27/1265	14.0	13.6	15.7	0	20	6.5	6.3	7.0	0	17	115.0	102.0	141.4	0	19
R27/6833	14.5	13.8	17.5	0	20	6.6	6.0	6.7	0	17	179.5	165.9	184.6	0	18
Wainuiomata															
R27/6418	13.6	12.0	15.3	0	20	5.7	5.3	5.9	0	17	180.5	145.9	196.5	0	18
Wairarapa Valley															
S26/0117	13.7	12.2	15.6	0	20	5.7	5.5	6.1	0	16	136.5	102.8	170.1	0	20
S26/0223	13.9	13.2	14.3	0	20	5.6	5.4	5.9	0	16	187.0	131.8	215.9	0	20
S26/0299	13.9	12.2	15.9	0	19	5.7	5.6	5.8	0	15	107.0	86.3	135.7	0	19
S26/0439	13.8	12.2	14.4	0	20	6.2	5.9	6.4	0	16	164.0	134.1	173.1	0	20
S26/0457	13.5	12.5	14.2	0	18	6.1	5.4	6.5	0	14	75.7	61.3	104.4	0	18
S26/0467	13.6	12.9	14.5	0	20	6.0	5.8	6.3	0	16	133.0	98.8	148.1	0	20
S26/0568	13.2	10.1	15.4	0	20	7.1	6.5	7.4	0	16	276.5	220.3	290.2	0	20
S26/0576	13.3	12.5	14.0	0	18	6.8	6.5	7.2	0	13	225.5	176.4	241.5	0	18
S26/0705	13.5	10.9	13.8	0	20	6.1	5.8	6.6	0	16	165.5	128.0	172.1	0	20
S26/0756	14.0	13.2	14.7	0	18	6.4	6.3	6.6	0	15	295.5	254.9	328.2	0	18
S26/0762	14.1	12.4	14.7	0	20	6.4	6.3	6.7	0	16	344.5	292.8	368.4	0	20
S26/0824	13.8	13.2	14.4	0	20	5.9	5.8	6.3	0	16	170.0	145.2	177.1	0	20
S26/0846	13.4	12.6	13.8	0	20	6.5	5.8	6.6	0	17	94.0	78.6	99.0	0	20
S27/0009	14.1	11.2	14.6	0	20	6.1	5.9	6.6	0	16	164.5	143.9	184.2	0	20
S27/0070	12.8	11.8	15.9	0	19	6.2	5.9	6.5	0	15	78.0	62.8	140.8	0	19
S27/0136	13.9	13.1	14.6	0	19	5.5	5.3	6.1	0	15	132.0	88.3	169.1	0	19
S27/0156	13.8	12.9	14.8	0	19	6.7	6.4	6.9	0	15	141.0	119.9	147.2	0	19
S27/0202	13.8	12.0	16.5	0	19	5.6	5.3	6.2	0	17	138.0	101.1	205.4	0	19
S27/0268	13.9	13.0	15.2	0	20	6.9	6.6	7.1	0	16	614.5	523.5	639.3	0	20
S27/0283	13.7	12.3	15.6	0	17	6.7	6.1	7.0	0	15	283.0	245.2	323.6	0	17
S27/0299	13.8	12.8	14.3	0	20	6.3	6.0	6.6	0	16	96.8	73.0	102.1	0	20
S27/0344	13.9	12.3	14.3	0	18	6.2	5.9	6.5	0	16	323.0	236.3	354.6	0	18

Site no.	Water temperature (°C)					pH					Conductivity (µS/cm)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S27/0389	14.7	14.2	15.6	0	20	6.9	6.3	7.1	0	17	196.0	161.5	201.0	0	20
S27/0396	14.0	13.3	15.3	0	19	6.8	6.5	7.1	0	17	534.0	361.8	578.1	0	19
S27/0433	14.6	13.7	15.2	0	19	6.8	6.5	6.9	0	14	833.0	619.3	872.8	0	19
S27/0435	14.0	13.1	15.2	0	20	6.6	6.4	6.9	0	16	369.5	308.4	397.1	0	20
S27/0442	14.7	13.6	15.0	0	20	7.4	7.0	7.5	0	16	641.5	543.9	677.7	0	20
S27/0495	13.8	12.8	14.2	0	19	6.8	6.2	7.1	0	15	659.0	496.4	810.3	0	19
S27/0522	14.8	14.3	24.2	0	20	6.6	6.5	6.9	0	17	769.5	658.8	801.3	0	20
S27/0571	14.6	14.2	15.5	0	20	6.5	6.2	6.6	0	17	267.5	207.8	289.0	0	20
S27/0585	14.4	13.4	14.8	0	19	6.7	6.4	7.1	0	14	480.0	378.3	506.1	0	19
S27/0588	13.6	13.1	14.0	0	20	6.5	6.2	6.9	0	16	193.0	161.5	205.0	0	19
S27/0594	14.0	12.9	15.2	0	17	7.3	6.8	7.5	0	13	560.0	451.8	598.4	0	17
S27/0602	13.8	12.6	14.6	0	19	7.0	6.4	7.2	0	15	441.0	351.4	453.7	0	19
S27/0607	14.4	13.4	14.5	0	19	6.6	6.2	6.9	0	16	1294.0	944.3	1548.9	0	19
S27/0614	13.9	13.0	14.5	0	21	6.8	6.5	7.1	0	17	419.0	352.0	477.0	0	21
S27/0615	13.8	13.2	14.3	0	21	6.7	6.1	6.9	0	17	372.0	285.0	405.0	0	21
S27/0681	14.0	12.3	15.2	0	19	6.9	6.5	7.2	0	16	423.0	360.2	471.1	0	19
T26/0003	13.5	11.0	15.5	0	20	5.9	5.3	6.3	0	17	84.2	67.7	127.6	0	20
T26/0087	13.4	12.9	13.8	0	20	6.3	6.1	6.7	0	16	124.0	105.1	148.1	0	20
T26/0099	13.6	13.1	13.9	0	20	6.2	5.9	6.5	0	16	160.5	137.7	172.2	0	20
T26/0206	13.7	13.2	14.2	0	20	7.2	6.8	7.4	0	16	161.5	135.4	169.0	0	20
T26/0259	13.7	12.3	15.4	0	20	6.1	5.8	6.4	0	15	88.5	74.7	140.1	0	20
T26/0332	14.2	13.8	14.8	0	20	5.9	5.8	6.2	0	16	212.5	170.3	224.0	0	20
T26/0413	14.0	13.5	14.5	0	20	7.1	6.6	7.3	0	16	179.0	150.3	186.1	0	20
T26/0430	13.6	12.1	15.2	0	20	6.0	5.6	6.5	0	16	103.5	86.4	141.5	0	20
T26/0489	13.1	12.8	13.4	0	20	6.0	5.9	6.3	0	16	290.5	220.5	308.3	0	20
T26/0538	13.4	12.2	14.8	0	20	5.8	5.7	6.1	0	15	349.5	294.2	406.5	0	20
Riversdale															
T27/0063	15.1	12.5	17.7	0	19	7.3	6.4	7.8	0	16	643.0	561.7	734.3	0	19

Site no.	Nitrite nitrate nitrogen (mg/L)					Dissolved reactive phosphorus (mg/L)					Total organic carbon (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	0.002	<0.002	0.019	55	20	0.302	0.006	0.374	10	20	1.95	1.49	3.28	0	20
R25/5135	0.002	0.001	0.005	58	19	0.390	0.267	0.452	0	19	1.10	0.38	2.57	21	19
R25/5164	0.41	0.274	0.819	0	19	0.182	0.099	0.283	0	19	1.89	1.30	3.48	0	19
R25/5165	0.017	0.003	0.434	0	19	0.300	0.241	0.361	0	19	3.60	2.07	5.35	0	19
R25/5190	5.09	3.60	8.54	0	20	0.088	0.067	0.110	0	20	3.11	2.20	5.17	0	20
R25/5233	1.6	1.11	2.00	0	20	0.012	0.009	0.017	0	20	1.65	1.08	2.70	0	20
R26/6503	0.018	0.008	0.201	0	20	0.011	0.002	0.079	50	20	2.20	1.67	3.47	0	20
R26/6587	0.67	0.404	1.25	0	17	0.008	0.005	0.010	0	17	1.00	0.11	1.77	6	17
R26/6624	2.90	2.44	3.43	0	19	0.021	0.016	0.025	0	19	2.10	1.07	3.35	5	19
S25/5125	2.60	0.85	4.40	0	21	0.018	0.014	0.021	0	21	1.70	0.28	3.32	14	21
S25/5200	0.003	0.001	0.008	39	18	0.136	0.111	0.150	0	18	0.96	0.27	2.64	0	18
S25/5256	9.60	8.46	10.54	0	19	0.018	0.014	0.022	0	19	1.40	0.12	2.90	16	19
S25/5322	9.90	9.40	11.00	0	21	0.048	0.042	0.053	0	21	1.80	0.90	3.15	0	21
Hutt Valley															
R27/0320	0.002	<0.002	0.016	50	20	0.150	0.138	0.166	0	20	1.72	0.62	2.50	10	20
R27/1137	1.04	0.466	1.81	0	20	0.005	0.003	0.009	30	20	0.78	0.17	2.47	20	20
R27/1171	<0.002	<0.002	0.009	81	16	0.219	0.118	0.232	0	16	1.55	0.81	2.89	0	16
R27/1180	0.848	0.727	1.10	0	20	0.012	0.010	0.015	0	20	1.62	0.15	3.41	5	20
R27/1182	0.81	0.738	0.86	0	20	0.008	0.006	0.010	10	20	1.63	1.07	3.05	0	20

Site no.	Nitrite nitrate nitrogen (mg/L)					Dissolved reactive phosphorus (mg/L)					Total organic carbon (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
R27/1183	0.313	0.238	0.466	0	20	0.009	0.007	0.013	0	20	0.74	0.27	1.40	5	20
R27/1265	0.2	0.143	0.22	5	20	0.018	0.013	0.043	0	20	0.53	0.05	1.91	20	20
R27/6833	0.571	0.266	1.43	0	20	0.048	0.031	0.056	0	20	1.54	0.67	3.86	0	20
Wainuiomata															
R27/6418	1.74	0.936	2.98	0	20	0.016	0.014	0.023	0	20	2.07	1.17	3.55	0	20
Wairarapa Valley															
S26/0117	3.40	2.178	7.10	0	20	0.016	0.012	0.019	0	20	2.20	1.09	3.46	0	20
S26/0223	9.15	5.62	11.72	0	20	0.018	0.014	0.024	0	20	1.09	0.17	2.55	5	20
S26/0299	2.70	2.07	4.63	0	19	0.021	0.015	0.024	0	19	1.10	0.42	2.69	0	19
S26/0439	3.50	3.05	3.99	0	20	0.024	0.011	0.027	0	20	2.24	0.89	2.93	0	20
S26/0457	0.432	0.237	1.53	0	18	0.009	0.006	0.013	0	18	0.60	0.21	1.88	11	18
S26/0467	2.00	1.30	3.63	0	20	0.020	0.017	0.023	0	20	1.95	0.96	2.97	0	20
S26/0568	0.005	0.002	0.021	10	20	1.00	0.681	1.35	0	20	1.67	0.44	3.38	0	20
S26/0576	0.004	<0.002	0.089	67	18	0.620	0.557	0.760	0	18	2.09	1.19	3.57	0	18
S26/0705	4.84	4.68	5.29	0	20	0.024	0.020	0.030	0	20	1.60	0.44	2.59	10	20
S26/0756	0.008	0.003	0.028	6	18	0.140	0.050	0.296	6	18	2.20	1.19	4.27	0	18
S26/0762	0.009	0.004	0.016	10	20	0.804	0.014	0.932	0	20	4.47	2.78	7.51	0	20
S26/0824	5.30	4.87	6.32	0	20	0.017	0.013	0.020	0	20	1.85	0.34	2.75	5	20
S26/0846	0.659	0.53	0.962	0	21	0.020	0.013	0.025	0	21	0.88	0.12	1.90	14	21
S27/0009	2.95	2.40	4.28	0	20	0.015	0.011	0.018	0	20	1.65	0.44	2.80	10	20
S27/0070	0.455	0.174	2.41	0	19	0.006	0.004	0.008	16	19	0.64	0.17	1.87	16	19
S27/0136	5.43	1.87	7.38	0	19	0.007	0.004	0.010	26	19	0.91	0.63	1.75	0	19
S27/0156	0.004	0.001	0.028	21	19	0.083	0.069	0.111	0	19	2.15	0.61	2.61	0	19
S27/0202	3.52	2.49	4.64	0	20	0.020	0.017	0.026	0	20	1.41	0.73	3.93	0	20
S27/0268	0.002	<0.002	0.021	50	20	0.010	<0.004	0.295	75	20	3.15	0.94	7.44	5	20
S27/0283	0.015	0.004	0.04	12	17	0.213	0.010	0.631	24	17	3.84	2.40	5.41	0	17
S27/0299	0.266	0.224	0.32	0	20	0.007	0.004	0.010	0	20	0.67	0.11	2.01	25	20
S27/0344	0.004	0.002	0.009	22	18	0.062	0.052	0.070	0	18	1.65	0.66	3.47	0	18
S27/0389	<0.002	<0.002	0.582	60	20	0.986	0.839	1.10	0	20	1.59	0.55	2.93	0	20
S27/0396	0.218	0.041	0.781	0	19	0.018	0.012	0.024	0	19	2.20	0.99	3.23	5	19
S27/0433	0.004	0.001	0.027	42	19	<0.004	<0.004	1.05	74	19	8.20	5.91	15.63	0	19
S27/0435	0.001	<0.002	0.007	65	20	4.81	3.28	5.21	0	20	6.96	3.80	10.08	0	20
S27/0442	0.003	0.003	0.003	90	20	3.90	3.70	4.13	0	20	1.95	1.08	3.21	0	20
S27/0495	0.009	0.002	0.049	16	19	0.310	0.019	0.856	37	19	3.41	1.78	5.91	0	19
S27/0522	3.28	3.00	3.47	0	20	0.003	0.001	0.009	60	20	1.86	0.63	3.03	0	20
S27/0571	9.22	7.94	10.15	0	20	0.010	0.007	0.012	0	20	1.70	0.20	2.70	15	20
S27/0585	0.003	0.001	0.01	32	19	0.345	0.210	0.406	16	19	1.90	0.19	3.44	5	19
S27/0588	0.007	0.003	0.012	25	20	0.143	0.061	0.166	15	20	2.12	0.44	2.72	5	20
S27/0594	0.001	<0.002	0.01	65	17	0.520	0.139	0.592	0	17	2.10	1.05	3.70	0	17
S27/0602	0.001	0.001	0.004	68	19	1.90	0.836	2.10	0	19	3.40	2.39	4.25	0	19
S27/0607	0.008	0.001	0.041	28	18	0.009	<0.004	1.75	37	19	8.30	2.52	11.58	0	19
S27/0614	0.005	0.001	0.025	29	21	0.537	0.007	0.730	0	21	2.40	1.40	3.24	0	21
S27/0615	0.008	0.002	0.047	14	21	0.273	0.005	0.750	5	21	2.72	1.20	4.32	0	21
S27/0681	0.212	0.072	0.809	0	19	0.014	0.010	0.018	0	19	2.09	1.08	3.70	0	19
T26/0003	1.87	0.384	5.14	0	20	0.018	0.013	0.021	0	20	0.65	0.26	1.29	10	20
T26/0087	0.98	0.251	2.87	0	20	0.024	0.009	0.051	0	20	2.19	0.68	3.61	0	20
T26/0099	5.61	4.29	7.19	0	20	0.015	0.012	0.018	0	20	1.80	0.41	2.71	5	20
T26/0206	1.54	1.30	1.79	0	20	0.064	0.060	0.072	0	20	1.77	0.40	2.83	0	20
T26/0259	1.03	0.42	3.71	0	20	0.007	0.005	0.011	5	20	1.10	0.34	2.93	10	20
T26/0332	0.745	0.527	1.18	0	20	0.043	0.038	0.051	0	20	2.70	1.88	3.86	0	20
T26/0413	0.001	<0.002	0.003	75	20	0.031	0.025	0.034	0	20	1.63	0.41	2.46	0	20
T26/0430	1.49	0.835	4.24	0	20	0.012	0.008	0.017	0	20	2.26	0.70	3.65	5	20
T26/0489	11.00	9.78	12.00	0	19	0.014	0.011	0.017	0	20	1.95	1.15	3.10	0	20
T26/0538	10.20	8.69	12.49	0	20	0.007	0.004	0.010	5	20	3.39	1.79	4.97	0	20
Riversdale															
T27/0063	2.33	0.857	7.85	0	19	0.076	0.064	0.085	0	19	2.60	0.13	4.24	0	9

Site no.	Calcium (mg/L)					Magnesium (mg/L)					Potassium (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	11.0	10.0	11.7	0	20	13.60	11.86	14.72	0	20	9.77	9.07	11.02	0	20
R25/5135	31.8	28.6	34.4	0	19	12.60	11.00	14.11	0	19	1.39	1.19	1.53	0	19
R25/5164	2.2	1.7	3.3	0	19	3.99	2.16	6.33	0	19	2.86	2.07	3.88	0	19
R25/5165	7.0	4.1	8.8	0	19	3.25	1.98	4.22	0	19	2.50	1.87	3.10	0	19
R25/5190	13.0	11.2	16.8	0	20	8.40	7.30	11.03	0	20	6.55	5.80	7.26	0	20
R25/5233	11.2	10.0	12.7	0	20	3.15	2.74	3.48	0	20	1.50	1.30	1.65	0	20
R26/6503	17.0	15.0	20.0	0	20	6.47	5.30	7.30	0	20	3.25	2.70	3.52	0	20
R26/6587	7.0	5.9	8.4	0	17	2.60	2.18	3.02	0	17	1.13	0.98	1.30	0	17
R26/6624	9.8	8.9	10.9	0	19	6.30	5.69	7.31	0	19	1.57	1.39	1.71	0	19
S25/5125	6.6	4.6	9.2	0	21	3.36	2.54	4.90	0	21	1.94	1.60	2.18	0	21
S25/5200	12.4	11.9	13.3	0	18	8.21	7.50	9.59	0	18	1.30	1.19	1.43	0	18
S25/5256	11.2	10.0	12.2	0	19	6.63	5.89	7.19	0	19	1.55	1.40	1.75	0	19
S25/5322	18.0	17.0	19.2	0	21	8.63	7.90	9.60	0	21	2.31	2.10	2.47	0	21
Hutt Valley															
R27/0320	4.1	3.7	4.5	0	20	2.19	2.00	2.43	0	20	0.71	0.65	0.79	0	20
R27/1137	6.5	5.7	7.8	0	20	2.21	1.80	2.87	0	20	1.05	0.87	1.42	0	20
R27/1171	4.6	4.3	5.3	0	16	4.46	4.00	4.96	0	16	1.73	1.60	2.22	0	16
R27/1180	8.3	7.0	9.0	0	20	3.10	2.77	3.50	0	20	1.12	1.08	1.39	0	20
R27/1182	11.7	10.0	12.1	0	20	6.32	5.67	6.93	0	20	1.80	1.60	1.96	0	20
R27/1183	5.4	4.7	6.2	0	20	1.90	1.68	2.20	0	20	0.92	0.84	1.06	0	20
R27/1265	4.2	4.0	4.7	0	20	2.40	2.20	2.71	0	20	0.97	0.88	1.10	0	20
R27/6833	8.3	7.8	8.8	0	20	5.50	5.19	6.02	0	20	0.78	0.71	0.92	0	20
Wainuiomata															
R27/6418	6.3	5.5	8.6	0	20	3.85	3.60	5.25	0	20	2.40	1.64	2.69	0	20
Wairarapa Valley															
S26/0117	8.7	7.3	11.1	0	20	3.20	2.53	4.02	0	20	2.69	2.29	2.88	0	20
S26/0223	11.1	8.2	13.5	0	20	5.42	3.83	6.45	0	20	1.09	0.92	1.35	0	20
S26/0299	6.9	6.0	9.5	0	19	2.41	2.19	3.39	0	19	0.94	0.83	1.40	0	19
S26/0439	10.3	9.5	11.4	0	20	4.96	4.38	5.59	0	20	1.10	1.00	1.24	0	20
S26/0457	7.2	6.8	9.9	0	18	1.40	1.18	1.82	0	18	0.82	0.77	0.94	0	18
S26/0467	6.7	6.1	7.4	0	20	2.62	2.40	2.96	0	20	1.62	1.54	1.83	0	20
S26/0568	21.0	20.0	23.1	0	20	9.19	8.49	10.04	0	20	1.20	1.10	1.30	0	20
S26/0576	15.0	14.0	16.4	0	18	5.96	5.37	6.50	0	18	1.00	0.90	1.10	0	18
S26/0705	8.9	8.3	9.3	0	20	4.06	3.72	4.54	0	20	1.10	0.97	1.26	0	20
S26/0756	29.5	25.6	35.7	0	18	6.16	5.11	7.05	0	18	1.71	1.44	1.83	0	18
S26/0762	21.7	18.6	23.6	0	20	6.48	5.40	7.21	0	20	2.00	1.70	2.14	0	20
S26/0824	9.6	8.9	10.3	0	20	4.74	4.34	5.38	0	20	1.20	1.10	1.26	0	20
S26/0846	8.1	7.4	8.6	0	21	2.04	1.80	2.27	0	21	0.73	0.65	0.81	0	21
S27/0009	10.0	9.5	11.5	0	20	4.10	3.67	4.73	0	20	1.42	1.30	1.59	0	20
S27/0070	6.8	6.0	13.3	0	19	1.30	1.10	2.65	0	19	0.77	0.69	1.11	0	19
S27/0136	7.4	4.2	10.3	0	19	3.50	1.96	5.33	0	19	1.04	0.78	1.30	0	19
S27/0156	7.2	6.5	7.6	0	19	2.93	2.60	3.22	0	19	0.79	0.71	0.92	0	19
S27/0202	7.8	6.4	8.7	0	20	3.60	2.80	4.20	0	20	1.33	1.10	1.45	0	20
S27/0268	52.2	45.0	54.8	0	20	23.50	19.90	26.13	0	20	2.13	1.90	2.32	0	20
S27/0283	13.0	12.0	15.0	0	17	6.46	5.70	7.28	0	17	1.60	1.36	1.80	0	17
S27/0299	7.0	6.2	7.4	0	20	2.55	2.30	2.73	0	20	0.80	0.69	0.85	0	20
S27/0344	17.0	15.8	18.2	0	18	7.19	6.72	7.96	0	18	1.70	1.60	1.84	0	18
S27/0389	7.7	7.1	8.7	0	20	4.78	4.28	5.20	0	20	1.19	1.00	1.37	0	20
S27/0396	73.0	51.1	79.1	0	19	9.16	6.64	10.11	0	19	2.40	1.67	2.65	0	19
S27/0433	50.1	44.4	54.2	0	19	22.00	18.00	24.07	0	19	7.65	6.79	8.67	0	19
S27/0435	14.5	12.9	15.0	0	20	6.30	5.39	7.10	0	20	4.10	3.89	4.61	0	20
S27/0442	7.9	7.0	8.5	0	20	2.90	2.50	3.21	0	20	0.96	0.80	1.09	0	20
S27/0495	32.0	25.9	41.5	0	19	12.00	9.99	16.64	0	19	2.50	2.19	3.24	0	19
S27/0522	31.2	27.0	33.2	0	20	18.45	15.95	20.01	0	20	2.12	1.89	2.47	0	20
S27/0571	13.8	12.0	15.2	0	20	6.03	5.39	7.01	0	20	1.62	1.49	1.81	0	20

Site no.	Calcium (mg/L)					Magnesium (mg/L)					Potassium (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S27/0585	16.1	14.5	17.0	0	19	13.00	11.58	14.05	0	19	1.70	1.50	1.82	0	19
S27/0588	10.0	9.5	10.6	0	20	3.84	3.53	4.21	0	20	1.50	1.30	1.70	0	20
S27/0594	35.3	33.0	37.4	0	17	12.00	10.94	13.00	0	17	2.50	2.18	2.70	0	17
S27/0602	23.0	20.7	25.5	0	19	7.90	6.59	8.56	0	19	5.26	4.59	5.82	0	19
S27/0607	49.0	30.9	55.5	0	19	24.00	14.08	25.46	0	19	8.20	6.40	8.76	0	19
S27/0614	22.9	16.7	25.6	0	21	6.92	4.90	8.16	0	21	3.46	2.90	3.98	0	21
S27/0615	16.0	11.4	18.0	0	21	7.00	5.06	8.00	0	21	2.48	2.20	4.77	0	21
S27/0681	54.6	48.9	63.6	0	19	6.30	5.30	8.06	0	19	1.90	1.79	2.26	0	19
T26/0003	6.1	4.4	9.4	0	20	1.89	1.40	2.91	0	20	0.77	0.61	0.92	0	20
T26/0087	10.2	8.6	12.2	0	20	2.50	2.22	2.82	0	20	1.03	0.94	1.24	0	20
T26/0099	9.0	7.8	10.5	0	20	5.10	4.44	5.76	0	20	1.21	1.10	1.47	0	20
T26/0206	9.4	8.6	10.2	0	20	3.89	3.50	4.20	0	20	0.80	0.73	0.90	0	20
T26/0259	8.3	6.9	12.1	0	20	1.52	1.20	2.13	0	20	0.79	0.68	1.05	0	20
T26/0332	11.0	10.7	12.2	0	20	4.84	4.50	5.41	0	20	1.04	0.94	1.27	0	20
T26/0413	13.2	12.0	14.7	0	20	5.08	4.79	5.50	0	20	0.91	0.84	1.05	0	20
T26/0430	9.1	7.2	11.1	0	20	2.21	1.74	3.01	0	20	1.20	0.99	1.56	0	20
T26/0489	27.6	24.9	28.6	0	20	4.63	4.21	5.24	0	20	1.60	1.40	1.92	0	20
T26/0538	31.0	27.9	36.0	0	20	9.15	8.59	12.00	0	20	3.64	3.20	4.24	0	20
Riversdale															
T27/0063	76.0	64.6	89.2	0	9	6.50	5.80	8.25	0	9	1.64	1.50	2.21	0	9

Site no.	Zinc (mg/L)					Bromide (mg/L)					Chloride (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	0.190	0.004	1.024	0	20	0.17	0.12	0.25	0	20	38.9	37.0	40.0	0	20
R25/5135	0.017	0.013	0.047	0	19	0.33	0.21	0.41	0	19	106.0	96.9	114.6	0	19
R25/5164	0.420	0.280	0.541	0	19	0.17	0.10	0.30	0	19	55.0	28.2	87.1	0	19
R25/5165	0.012	0.008	0.032	0	19	0.09	0.04	0.23	21	19	31.0	14.9	40.1	0	19
R25/5190	0.004	0.002	0.011	0	20	0.10	0.05	0.19	10	20	26.5	23.2	36.1	0	20
R25/5233	0.004	0.002	0.018	0	20	0.04	0.01	0.12	50	20	12.7	10.4	15.1	0	20
R26/6503	0.008	0.003	0.025	0	20	0.06	0.03	0.14	45	20	41.0	37.0	42.9	0	20
R26/6587	0.005	0.003	0.046	0	17	0.08	0.04	0.18	24	17	18.5	17.0	24.0	0	17
R26/6624	0.012	0.002	0.072	0	19	0.12	0.06	0.30	11	19	26.5	24.0	28.6	0	19
S25/5125	0.004	0.002	0.009	0	21	0.06	0.04	0.11	38	21	15.0	10.2	23.0	0	21
S25/5200	0.009	0.004	0.056	0	18	0.15	0.12	0.25	0	18	38.0	37.0	39.0	0	18
S25/5256	0.099	0.053	0.145	0	19	0.12	0.06	0.20	16	19	25.0	24.2	26.0	0	19
S25/5322	0.005	0.002	0.010	0	21	0.19	0.12	0.31	0	21	30.7	29.8	31.7	0	21
Hutt Valley															
R27/0320	0.004	0.002	0.009	0	20	0.09	0.04	0.16	10	20	25.0	24.0	25.9	0	20
R27/1137	0.016	0.004	0.052	0	20	0.06	0.01	0.25	45	20	12.0	11.0	13.0	0	20
R27/1171	0.005	0.002	0.017	0	16	0.09	0.04	0.22	12	16	14.6	14.0	15.6	0	16
R27/1180	0.011	0.008	0.030	0	20	0.08	0.03	0.15	25	20	16.1	15.0	17.0	0	20
R27/1182	0.093	0.050	0.240	0	20	0.11	0.05	0.19	5	20	18.2	17.8	19.0	0	20
R27/1183	0.004	0.002	0.009	0	20	0.06	0.04	0.07	60	20	14.0	12.4	15.0	0	20
R27/1265	0.005	0.003	0.012	0	20	0.08	0.03	0.14	25	20	14.5	13.9	18.4	0	20
R27/6833	0.016	0.007	0.027	0	20	0.09	0.05	0.15	15	20	12.9	12.0	13.1	0	20
Wainuiomata															
R27/6418	0.013	0.004	0.040	0	20	0.13	0.05	0.25	5	20	27.0	21.0	29.1	0	20
Wairarapa Valley															
S26/0117	0.004	0.001	0.021	5	20	0.03	0.01	0.14	65	20	13.0	12.0	17.0	0	20
S26/0223	0.007	0.004	0.028	0	20	0.06	0.02	0.13	45	20	17.0	12.1	19.1	0	20

Site no.	Zinc (mg/L)					Bromide (mg/L)					Chloride (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S26/0299	0.008	0.006	0.022	0	19	0.03	0.01	0.10	63	19	8.8	7.4	13.6	0	19
S26/0439	0.008	0.004	0.053	0	20	0.06	0.01	0.20	40	20	15.0	14.0	15.3	0	20
S26/0457	0.010	0.003	0.021	0	18	0.08	0.08	0.08	94	18	5.9	5.2	8.7	0	18
S26/0467	0.010	0.005	0.014	0	20	0.06	0.01	0.18	40	20	12.2	11.1	14.0	0	20
S26/0568	0.002	0.001	0.003	15	20	0.07	0.02	0.22	35	20	12.7	11.9	13.0	0	20
S26/0576	0.005	0.002	0.020	6	18	0.07	0.04	0.12	22	18	18.0	16.4	20.0	0	18
S26/0705	0.006	0.002	0.035	0	20	0.08	0.03	0.22	20	20	12.0	11.4	13.0	0	20
S26/0756	0.010	0.003	0.045	0	18	0.08	0.02	0.25	33	18	25.0	22.0	30.2	0	18
S26/0762	0.002	0.001	0.008	15	20	0.17	0.13	0.30	0	20	45.0	38.6	48.7	0	20
S26/0824	0.005	0.002	0.016	0	20	0.07	0.02	0.22	20	20	13.2	12.7	14.0	0	20
S26/0846	0.003	0.001	0.004	0	21	0.25	0.25	0.25	95	21	6.3	6.0	7.0	0	21
S27/0009	0.002	0.001	0.014	0	20	0.07	0.02	0.20	25	20	18.3	17.1	21.1	0	20
S27/0070	0.004	0.003	0.007	0	19	0.01	0.00	0.05	89	19	7.5	6.3	14.1	0	19
S27/0136	0.003	0.002	0.012	0	19	0.07	0.02	0.23	26	19	13.0	9.5	18.1	0	19
S27/0156	0.010	0.003	0.036	0	19	0.06	0.03	0.16	16	19	13.0	12.9	14.0	0	19
S27/0202	0.011	0.003	0.026	0	20	0.08	0.03	0.24	30	20	15.9	12.0	18.0	0	20
S27/0268	0.010	0.003	0.017	0	20	0.12	0.09	0.32	0	20	17.9	17.0	18.5	0	20
S27/0283	0.007	0.002	0.016	0	17	0.16	0.11	0.32	0	17	35.0	28.0	41.6	0	17
S27/0299	0.003	0.001	0.007	5	20	<0.05	<0.05	0.06	90	20	8.4	7.7	8.6	0	20
S27/0344	0.016	0.004	0.043	0	18	0.19	0.13	0.31	6	18	56.5	48.8	64.9	0	18
S27/0389	0.006	0.003	0.009	0	20	0.09	0.03	0.23	20	20	22.0	21.0	22.8	0	20
S27/0396	0.013	0.002	0.032	0	19	0.13	0.03	0.35	21	19	36.0	25.4	38.1	0	19
S27/0433	0.005	0.002	0.020	0	19	0.52	0.40	0.59	0	19	89.0	84.8	93.1	0	19
S27/0435	0.008	0.004	0.014	0	20	0.17	0.13	0.35	0	20	34.0	33.2	35.1	0	20
S27/0442	0.016	0.009	0.031	0	20	0.35	0.25	0.50	0	20	98.5	93.3	102.1	0	20
S27/0495	0.027	0.009	0.061	0	19	0.55	0.28	0.78	5	19	120.0	91.9	148.6	0	19
S27/0522	0.015	0.010	0.030	0	20	0.52	0.40	0.69	0	20	140.5	130.0	155.8	0	20
S27/0571	0.016	0.004	0.029	0	20	0.13	0.06	0.20	10	20	32.1	27.1	35.1	0	20
S27/0585	0.008	0.002	0.031	0	19	0.22	0.16	0.31	0	19	53.0	50.9	57.0	0	19
S27/0588	0.003	0.002	0.007	5	20	0.09	0.06	0.18	5	20	26.2	24.8	28.0	0	20
S27/0594	0.001	<0.001	0.002	53	17	0.31	0.27	0.39	0	17	84.8	78.8	90.4	0	17
S27/0602	0.002	0.001	0.005	11	19	0.25	0.19	0.44	0	19	64.9	60.4	67.6	0	19
S27/0607	0.007	0.003	0.041	0	19	1.30	0.64	1.61	0	19	310.0	174.5	337.3	0	19
S27/0614	0.006	0.002	0.068	0	21	0.23	0.16	0.38	0	21	63.0	50.0	69.3	0	21
S27/0615	0.004	0.002	0.013	0	21	0.21	0.13	0.31	0	21	54.2	43.3	59.2	0	21
S27/0681	0.006	0.003	0.021	0	19	0.12	0.05	0.28	11	19	32.9	29.2	37.0	0	19
T26/0003	0.004	0.002	0.012	0	20	0.03	0.00	0.20	55	20	8.9	7.6	12.3	0	20
T26/0087	0.012	0.005	0.046	0	20	0.01	0.00	0.12	75	20	6.9	5.5	10.5	0	20
T26/0099	0.002	0.001	0.004	5	20	0.06	0.02	0.14	35	20	11.1	10.0	12.5	0	20
T26/0206	0.005	0.004	0.006	0	20	0.06	0.02	0.19	35	20	11.3	11.0	12.0	0	20
T26/0259	0.008	0.004	0.018	0	20	0.02	0.01	0.06	90	20	6.7	5.3	11.7	0	20
T26/0332	0.006	0.001	0.011	5	20	0.11	0.04	0.26	20	20	30.5	27.8	32.4	0	20
T26/0413	0.010	0.003	0.030	0	20	0.06	0.02	0.15	40	20	9.7	9.4	10.0	0	20
T26/0430	0.001	<0.001	0.004	30	20	0.02	0.01	0.06	85	20	7.0	5.9	12.1	0	20
T26/0489	0.031	0.007	0.263	0	20	0.10	0.02	0.31	20	20	24.0	23.0	25.1	0	20
T26/0538	0.004	0.003	0.014	0	20	0.04	0.01	0.13	55	20	29.7	25.1	42.1	0	20
Riversdale															
T27/0063	0.002	0.001	0.003	33	9	0.12	0.04	0.29	22	9	54.0	44.2	69.3	0	9

Site no.	Boron (mg/L)					Dissolved reactive silica (mg/L)					Total alkalinity (mg/L as $CaCO_3$)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	0.066	0.055	0.076	0	20	36.4	30.9	38.1	0	20	110.0	105.0	120.0	0	20
R25/5135	2.53	2.38	2.80	0	19	26.5	25.8	28.0	0	19	120.0	116.9	128.2	0	19
R25/5164	0.025	0.017	0.035	0	19	0.5	0.2	3.6	0	19	5.0	3.0	13.4	0	19
R25/5165	0.026	0.019	0.033	0	19	30.0	25.9	33.6	0	19	28.0	21.9	31.4	0	19
R25/5190	0.028	0.024	0.036	0	20	55.0	52.7	60.2	0	20	66.5	57.0	78.2	0	20
R25/5233	0.024	0.022	0.027	0	20	14.0	13.3	15.1	0	20	36.5	33.0	87.3	0	20
R26/6503	0.030	0.025	0.037	0	20	22.3	20.5	25.0	0	20	48.0	40.0	55.0	0	20
R26/6587	0.021	0.018	0.028	0	17	13.0	12.4	14.0	0	17	24.0	19.8	26.0	0	17
R26/6624	0.037	0.035	0.043	0	19	20.0	19.0	21.0	0	19	52.0	43.5	56.1	0	19
S25/5125	0.020	0.017	0.024	0	21	14.1	12.0	16.7	0	21	19.0	17.0	21.0	0	21
S25/5200	0.032	0.027	0.034	0	18	38.3	37.2	40.2	0	18	80.5	76.7	84.5	0	18
S25/5256	0.028	0.026	0.031	0	19	23.0	22.5	24.1	0	19	23.0	21.0	24.1	0	19
S25/5322	0.024	0.022	0.028	0	21	58.0	55.9	60.0	0	21	66.0	64.0	69.0	0	21
Hutt Valley															
R27/0320	0.030	0.026	0.034	0	20	20.0	19.1	21.0	0	20	52.0	47.9	54.1	0	20
R27/1137	0.024	0.017	0.046	0	20	13.7	10.4	16.0	0	20	25.0	21.0	27.1	0	20
R27/1171	0.024	0.022	0.028	0	16	24.0	22.8	24.3	0	16	54.5	52.0	57.3	0	16
R27/1180	0.026	0.023	0.032	0	20	16.1	15.8	17.1	0	20	30.0	28.0	32.3	0	20
R27/1182	0.030	0.026	0.032	0	20	18.4	17.9	19.0	0	20	60.5	56.7	62.1	0	20
R27/1183	0.017	0.013	0.020	0	20	11.0	10.1	12.0	0	20	20.5	18.0	23.1	0	20
R27/1265	0.026	0.022	0.029	0	20	18.4	17.6	19.5	0	20	28.0	27.0	34.1	0	20
R27/6833	0.028	0.026	0.030	0	20	27.0	24.9	27.1	0	20	71.0	61.7	75.1	0	20
Wainuiomata															
R27/6418	0.024	0.016	0.037	0	20	17.0	16.0	18.8	0	20	24.5	19.0	30.1	0	20
Wairarapa Valley															
S26/0117	0.020	0.018	0.024	0	20	15.0	13.9	15.1	0	20	24.0	21.0	27.0	0	20
S26/0223	0.013	0.010	0.015	0	20	16.1	14.5	18.1	0	20	15.0	12.0	19.0	0	20
S26/0299	0.017	0.014	0.020	0	19	13.0	12.0	13.4	0	19	15.0	11.0	17.1	0	19
S26/0439	0.016	0.013	0.019	0	20	22.3	19.9	24.1	0	20	33.5	28.6	38.1	0	20
S26/0457	0.014	0.012	0.019	0	18	8.8	8.4	9.1	0	18	23.5	19.9	26.2	0	18
S26/0467	0.030	0.026	0.033	0	20	19.0	18.0	20.0	0	20	27.0	26.0	30.1	0	20
S26/0568	0.020	0.018	0.023	0	20	36.5	35.7	38.1	0	20	127.5	120.0	130.0	0	20
S26/0576	0.021	0.018	0.024	0	18	34.0	32.3	35.2	0	18	83.5	78.0	87.2	0	18
S26/0705	0.034	0.030	0.037	0	20	26.0	25.0	27.0	0	20	34.0	31.9	36.0	0	20
S26/0756	0.032	0.027	0.036	0	18	19.9	17.0	22.7	0	18	100.0	91.0	107.0	0	18
S26/0762	0.056	0.047	0.067	0	20	24.2	23.0	25.1	0	20	100.0	94.8	110.0	0	20
S26/0824	0.042	0.038	0.046	0	20	23.3	22.0	24.7	0	20	31.0	28.0	33.5	0	20
S26/0846	0.016	0.014	0.019	0	21	13.7	12.9	14.0	0	21	32.0	31.0	34.0	0	21
S27/0009	0.031	0.027	0.034	0	20	17.4	16.8	18.1	0	20	32.0	30.0	33.1	0	20
S27/0070	0.019	0.013	0.022	0	19	8.7	7.9	9.4	0	19	21.0	19.0	33.1	0	19
S27/0136	0.012	0.011	0.013	0	19	14.4	11.9	15.1	0	19	11.0	8.8	16.0	0	19
S27/0156	0.021	0.018	0.025	0	19	23.0	22.0	24.0	0	19	50.0	47.0	52.1	0	19
S27/0202	0.013	0.010	0.015	0	20	14.9	13.4	16.0	0	20	12.4	11.0	15.0	0	20
S27/0268	0.026	0.023	0.030	0	20	29.0	27.0	31.1	0	20	310.0	295.3	330.0	0	20
S27/0283	0.030	0.025	0.035	0	17	36.0	33.0	38.0	0	17	89.0	81.4	98.8	0	17
S27/0299	0.020	0.017	0.022	0	20	14.1	13.9	15.0	0	20	31.0	29.0	32.1	0	20
S27/0344	0.035	0.033	0.037	0	18	23.7	22.8	25.0	0	18	59.0	54.9	61.0	0	18
S27/0389	0.040	0.038	0.045	0	20	34.9	32.1	38.0	0	20	58.0	55.0	60.1	0	20
S27/0396	0.039	0.033	0.046	0	19	11.0	10.2	12.0	0	19	197.0	124.5	216.4	0	19
S27/0433	0.086	0.078	0.090	0	19	40.0	38.9	42.1	0	19	290.0	270.0	300.0	0	19
S27/0435	0.088	0.078	0.096	0	20	39.9	38.0	41.1	0	20	121.0	115.9	130.0	0	20
S27/0442	0.166	0.140	0.180	0	20	27.0	25.5	28.0	0	20	160.0	155.9	170.0	0	20
S27/0495	0.062	0.057	0.076	0	19	30.5	28.9	32.1	0	19	150.0	140.0	160.0	0	19
S27/0522	0.049	0.045	0.058	0	20	23.8	22.7	25.2	0	20	100.0	97.0	104.3	0	20
S27/0571	0.024	0.021	0.028	0	20	27.9	26.3	29.0	0	20	38.0	35.9	40.0	0	20
S27/0585	0.038	0.034	0.042	0	19	25.0	21.6	26.0	0	19	170.0	155.5	180.0	0	19

Site no.	Boron (mg/L)					Dissolved reactive silica (mg/L)					Total alkalinity (mg/L as $CaCO_3$)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S27/0588	0.031	0.029	0.034	0	20	13.8	13.0	14.0	0	20	43.5	39.0	47.1	0	20
S27/0594	0.080	0.070	0.085	0	17	25.6	24.7	26.2	0	17	160.0	149.4	160.2	0	17
S27/0602	0.055	0.048	0.061	0	19	51.0	48.9	55.0	0	19	112.0	108.3	120.1	0	19
S27/0607	0.160	0.139	0.180	0	19	38.0	36.0	40.2	0	19	200.0	182.0	211.2	0	19
S27/0614	0.042	0.036	0.047	0	21	49.0	47.0	52.0	0	21	112.0	87.0	126.0	0	21
S27/0615	0.039	0.028	0.042	0	21	32.0	30.1	34.0	0	21	76.0	50.0	84.0	0	21
S27/0681	0.037	0.034	0.044	0	19	9.9	9.4	11.0	0	19	154.0	134.5	161.0	0	19
T26/0003	0.013	0.010	0.015	0	20	11.6	10.8	12.0	0	20	16.0	15.0	18.0	0	20
T26/0087	0.020	0.017	0.024	0	20	13.1	11.6	15.0	0	20	43.0	38.9	49.2	0	20
T26/0099	0.013	0.012	0.016	0	20	18.9	18.0	19.4	0	20	31.0	29.0	33.1	0	20
T26/0206	0.020	0.017	0.024	0	20	15.0	14.0	16.0	0	20	58.0	55.9	61.1	0	20
T26/0259	0.012	0.011	0.014	0	20	8.9	8.5	9.5	0	20	25.5	21.0	32.1	0	20
T26/0332	0.020	0.017	0.022	0	20	40.0	38.1	42.1	0	20	40.0	38.0	42.0	0	20
T26/0413	0.018	0.017	0.020	0	20	20.8	19.9	22.0	0	20	79.5	75.0	83.1	0	20
T26/0430	0.019	0.017	0.024	0	20	12.0	11.0	12.5	0	20	28.5	25.9	31.1	0	20
T26/0489	0.018	0.016	0.022	0	20	31.0	29.9	33.0	0	20	48.0	45.0	51.1	0	20
T26/0538	0.021	0.017	0.025	0	20	19.0	17.8	20.1	0	20	38.0	34.0	43.0	0	20
Riversdale															
T27/0063	0.043	0.031	0.062	0	9	7.2	6.6	8.0	0	9	220.0	199.8	230.0	0	9

Site no.	Dissolved oxygen (mg/L)					Bicarbonate (mg/L)					Sodium (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	0.14	0.03	0.91	5	20	137.5	128.0	141.1	0	20	33.00	29.90	35.28	0	20
R25/5135	0.30	0.03	1.12	0	17	150.0	140.9	156.4	0	19	67.00	59.90	70.20	0	19
R25/5164	7.35	4.14	8.80	0	19	6.0	3.7	16.4	0	19	29.90	18.19	47.92	0	19
R25/5165	0.12	0.03	0.99	5	19	34.0	26.9	37.6	0	19	21.00	11.97	27.17	0	19
R25/5190	4.35	2.51	8.04	0	20	80.5	69.0	94.4	0	20	25.00	21.00	26.03	0	20
R25/5233	3.32	2.89	4.51	0	20	44.5	40.0	110.0	0	20	11.00	9.55	35.35	0	20
R26/6503	0.36	0.08	3.21	0	20	58.0	49.0	67.0	0	20	26.00	22.95	27.31	0	20
R26/6587	6.88	5.22	8.24	0	16	29.0	23.8	32.0	0	17	13.80	11.80	15.20	0	17
R26/6624	2.69	1.27	3.60	0	19	63.0	53.3	68.1	0	19	26.30	23.80	30.10	0	19
S25/5125	5.55	3.99	6.89	0	19	23.0	21.0	26.0	0	21	12.00	9.86	14.80	0	21
S25/5200	0.17	0.01	1.34	0	18	98.0	92.7	102.4	0	18	32.00	28.85	34.30	0	18
S25/5256	6.34	4.80	7.95	0	19	28.0	25.9	29.1	0	19	23.00	20.90	24.90	0	19
S25/5322	5.32	3.99	6.81	0	21	81.0	78.0	84.0	0	21	32.70	30.00	35.00	0	21
Hutt Valley															
R27/0320	0.28	0.04	1.62	0	20	63.0	57.8	65.1	0	20	32.00	28.48	33.72	0	20
R27/1137	3.08	0.97	10.12	0	19	30.5	25.0	33.1	0	20	9.97	9.02	11.20	0	20
R27/1171	0.20	0.06	1.78	0	13	66.5	63.8	69.3	0	16	18.00	16.75	19.85	0	16
R27/1180	1.61	0.81	5.00	0	19	37.0	34.0	39.4	0	20	12.65	11.38	14.01	0	20
R27/1182	0.19	0.04	0.97	0	18	74.0	69.6	76.1	0	20	19.15	17.67	21.05	0	20
R27/1183	4.11	1.73	6.44	0	19	25.0	22.0	28.1	0	20	9.93	9.08	11.05	0	20
R27/1265	0.28	0.09	1.26	0	20	35.0	32.0	42.3	0	20	14.15	12.95	20.70	0	20
R27/6833	0.60	0.15	2.16	0	18	86.5	74.7	91.1	0	20	20.95	19.60	23.03	0	20
Wainuiomata															
R27/6418	4.56	2.17	6.57	0	18	63.0	57.8	65.1	0	20	19.60	16.86	22.55	0	20
Wairarapa Valley															
S26/0117	4.80	3.69	6.47	0	20	29.0	26.0	33.0	0	29.0	10.50	8.89	11.74	0	20
S26/0223	7.89	5.45	9.83	0	20	18.0	15.0	23.0	0	18.0	13.00	10.95	17.05	0	20
S26/0299	7.83	6.37	9.04	0	19	18.0	13.9	21.2	0	18.0	7.70	7.34	9.45	0	19
S26/0439	5.69	4.89	9.27	0	19	41.5	35.5	46.1	0	41.5	13.00	11.98	14.73	0	20

Site no.	Dissolved oxygen (mg/L)					Bicarbonate (mg/L)					Sodium (mg/L)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S26/0457	3.86	1.63	6.15	0	18	28.5	24.0	31.3	0	28.5	5.01	4.46	5.84	0	18
S26/0467	4.31	2.77	6.04	0	20	33.0	31.0	36.1	0	33.0	14.00	12.48	15.82	0	20
S26/0568	0.10	0.01	1.82	5	20	150.0	147.9	160.0	0	150.0	21.00	19.98	22.91	0	20
S26/0576	0.22	0.03	1.20	11	18	100.0	95.0	110.0	0	100.0	20.40	19.00	22.58	0	18
S26/0705	1.01	0.71	1.52	0	20	41.0	38.9	44.0	0	41.0	16.50	15.00	18.15	0	20
S26/0756	0.22	0.04	1.31	0	18	122.5	110.0	130.0	0	122.5	17.95	15.43	20.02	0	18
S26/0762	0.37	0.02	1.03	0	20	125.0	115.7	131.0	0	125.0	35.00	31.90	38.09	0	20
S26/0824	2.02	1.57	3.10	0	20	38.0	35.0	40.6	0	38.0	14.40	13.90	16.25	0	20
S26/0846	3.36	2.42	3.70	0	20	39.0	37.0	42.0	0	39.0	7.90	7.10	8.69	0	21
S27/0009	5.53	4.12	6.42	0	20	38.5	36.9	40.1	0	38.5	14.50	13.10	15.92	0	20
S27/0070	5.07	3.77	7.08	0	19	26.0	23.0	41.0	0	26.0	5.90	5.39	8.51	0	19
S27/0136	7.71	4.29	9.98	0	19	13.0	11.0	19.1	0	13.0	10.30	7.93	12.81	0	19
S27/0156	2.97	0.15	6.24	0	19	60.0	57.9	63.2	0	60.0	17.00	15.90	19.37	0	19
S27/0202	4.77	2.16	7.18	0	19	15.3	13.0	19.0	0	15.3	11.00	9.69	12.05	0	20
S27/0268	0.16	0.03	1.05	5	20	380.0	360.1	400.5	0	380.0	47.30	44.00	52.07	0	20
S27/0283	0.35	0.05	2.79	6	17	110.0	99.2	120.8	0	110.0	31.00	26.00	36.44	0	17
S27/0299	0.40	0.24	1.86	5	20	37.5	35.0	39.1	0	37.5	8.00	7.47	8.30	0	20
S27/0344	0.20	0.05	0.62	11	18	72.0	66.9	75.0	0	72.0	32.00	29.93	34.15	0	18
S27/0389	0.15	0.01	0.72	0	20	70.0	67.0	74.1	0	70.0	25.55	22.00	28.00	0	20
S27/0396	0.45	0.11	0.89	0	19	240.0	151.7	263.7	0	240.0	26.30	21.40	31.03	0	19
S27/0433	0.15	0.02	0.30	11	19	350.0	329.9	363.2	0	350.0	71.00	64.00	75.02	0	19
S27/0435	0.14	0.02	0.30	10	20	150.0	140.9	157.2	0	150.0	36.00	33.48	38.01	0	20
S27/0442	0.15	0.04	0.40	16	19	198.5	189.8	204.3	0	198.5	124.50	110.00	133.60	0	20
S27/0495	0.20	0.05	2.51	5	19	180.0	170.0	195.0	0	180.0	80.00	70.60	101.10	0	19
S27/0522	4.78	3.61	5.43	0	20	121.5	118.0	130.0	0	121.5	96.30	84.00	104.25	0	20
S27/0571	1.40	0.47	3.22	0	20	46.0	43.9	49.0	0	46.0	26.90	25.00	29.34	0	20
S27/0585	0.23	0.08	0.56	0	19	210.0	189.2	220.0	0	210.0	64.00	59.95	67.69	0	19
S27/0588	0.19	0.03	2.05	11	19	53.0	47.0	57.1	0	53.0	18.40	16.90	20.05	0	20
S27/0594	0.19	0.02	1.74	12	17	190.0	187.0	200.0	0	190.0	59.00	53.86	62.92	0	17
S27/0602	0.16	0.02	1.36	11	19	140.0	131.2	150.0	0	140.0	44.00	40.90	47.10	0	19
S27/0607	0.25	0.09	1.63	11	19	240.0	220.9	257.3	0	240.0	167.00	119.10	181.20	0	19
S27/0614	0.14	0.02	0.48	10	21	138.0	106.0	152.0	0	138.0	48.80	43.00	54.70	0	21
S27/0615	0.15	0.02	3.11	10	21	93.0	61.0	100.0	0	93.0	40.70	34.10	43.70	0	21
S27/0681	2.62	1.22	3.91	0	19	188.0	163.6	201.0	0	188.0	25.00	22.90	28.28	0	19
T26/0003	7.24	5.64	8.01	0	20	19.5	18.0	22.1	0	19.5	7.30	6.33	8.59	0	20
T26/0087	3.51	1.16	5.56	0	20	53.0	47.0	60.2	0	53.0	11.20	9.20	13.02	0	20
T26/0099	5.69	4.41	6.12	0	20	38.0	35.0	41.1	0	38.0	13.00	11.00	14.11	0	20
T26/0206	0.68	0.18	11.75	0	20	71.0	67.9	75.1	0	71.0	17.95	16.48	19.31	0	20
T26/0259	5.91	4.86	6.85	0	20	31.5	26.0	38.1	0	31.5	6.80	5.26	7.97	0	20
T26/0332	0.18	0.04	0.35	0	20	49.0	46.0	51.0	0	49.0	20.45	18.10	24.00	0	20
T26/0413	0.17	0.01	0.95	5	20	97.0	91.0	100.1	0	97.0	16.00	14.98	17.53	0	20
T26/0430	6.48	3.70	7.44	0	20	35.0	31.9	37.1	0	35.0	8.11	6.78	9.27	0	20
T26/0489	2.49	1.74	3.48	0	20	58.5	55.0	62.1	0	58.5	19.00	17.19	21.01	0	20
T26/0538	4.40	3.09	7.11	0	20	46.5	42.0	52.1	0	46.5	18.85	16.68	22.10	0	20
Riversdale															
T27/0063	6.54	3.49	8.99	0	19	270.0	238.0	276.0	0	270.0	40.00	33.40	47.72	0	9

Site number	Sulphate (mg/L)					Free CO_2 (mg/L at 25°C)					Total hardness (mg/L as $CaCO_3$)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
Kapiti Coast															
R25/5100	4.3	2.2	5.0	0	20	18.5	11.0	33.0	0	20	83.0	73.8	90.0	0	20
R25/5135	0.5	0.3	0.9	58	19	11.0	5.9	19.8	0	19	130.0	118.1	140.8	0	19
R25/5164	8.1	4.5	12.0	0	19	3.0	1.1	6.4	0	19	21.0	16.0	33.0	0	19
R25/5165	11.0	8.0	13.9	0	19	10.0	3.5	17.7	0	19	31.0	18.0	38.9	0	19
R25/5190	7.5	3.8	12.5	0	20	19.0	11.0	31.2	0	20	65.5	60.0	86.3	0	20
R25/5233	8.1	7.1	9.3	0	20	30.0	3.9	49.1	0	20	42.0	36.0	46.1	0	20
R26/6503	24.0	16.2	28.3	0	20	21.5	8.4	35.2	0	20	70.5	59.9	78.1	0	20
R26/6587	7.2	6.2	8.7	0	17	13.0	6.5	23.2	0	17	28.0	23.8	33.4	0	17
R26/6624	12.2	11.9	13.2	0	19	29.0	16.8	47.4	0	19	51.0	45.9	57.1	0	19
S25/5125	9.5	7.2	14.0	0	21	21.0	11.0	36.0	0	21	30.0	22.0	43.0	0	21
S25/5200	3.7	3.5	5.5	0	18	32.0	20.2	49.8	0	18	65.0	60.7	72.1	0	18
S25/5256	15.6	14.6	17.7	0	19	24.0	8.6	45.0	0	19	55.0	50.9	60.0	0	19
S25/5322	8.0	7.8	9.4	0	21	27.0	17.0	40.0	0	21	80.0	74.0	85.0	0	21
Hutt Valley															
R27/0320	2.9	2.6	3.3	0	20	4.6	3.1	8.7	0	20	19.0	18.0	21.1	0	20
R27/1137	5.1	4.1	8.5	5	20	20.0	9.6	29.7	0	20	25.5	22.0	31.1	0	20
R27/1171	0.5	0.5	0.5	88	16	16.0	9.3	29.0	0	16	30.5	27.8	33.3	0	16
R27/1180	7.6	7.0	8.3	0	20	29.0	12.9	40.2	0	20	33.5	29.0	37.1	0	20
R27/1182	9.3	8.7	9.9	5	20	34.5	16.9	48.8	0	20	56.0	49.9	59.0	0	20
R27/1183	4.4	3.8	5.0	0	20	12.5	5.0	16.1	0	20	21.0	19.0	25.0	0	20
R27/1265	4.4	3.9	4.8	0	20	7.6	4.0	14.4	0	20	20.0	19.0	23.1	0	20
R27/6833	2.6	2.4	2.9	0	20	22.5	15.8	37.2	0	20	44.0	41.0	48.0	0	20
Wainuiomata															
R27/6418	11.0	9.4	18.6	0	20	46.5	20.5	64.1	0	20	32.0	29.0	43.0	0	20
Wairarapa Valley															
S26/0117	8.4	7.0	9.4	0	20	32.5	17.7	45.4	0	20	35.0	28.9	44.3	0	20
S26/0223	11.9	8.7	16.0	0	20	28.0	4.0	40.1	0	20	50.5	35.8	59.3	0	20
S26/0299	10.8	9.2	12.1	0	19	21.0	5.5	31.8	0	19	27.0	24.7	38.1	0	19
S26/0439	11.0	10.2	12.2	0	20	22.0	15.0	29.1	0	20	47.0	41.8	52.0	0	20
S26/0457	4.7	3.8	5.6	0	18	14.5	7.9	19.8	0	18	23.5	21.9	32.5	0	18
S26/0467	9.0	8.1	9.9	0	20	25.0	13.0	31.0	0	20	27.5	25.0	31.0	0	20
S26/0568	0.5	0.5	0.5	95	20	14.0	10.9	23.1	0	20	90.5	85.9	99.2	0	20
S26/0576	2.5	1.5	3.9	0	18	13.5	8.5	25.1	0	18	63.0	57.7	67.0	0	18
S26/0705	9.7	9.2	11.0	0	20	23.5	9.9	31.8	0	20	39.0	36.0	42.0	0	20
S26/0756	11.0	8.1	13.6	0	18	42.5	31.9	52.4	0	18	97.5	85.2	119.0	0	18
S26/0762	1.0	0.3	2.0	30	20	41.5	29.8	59.2	0	20	80.5	69.0	88.2	0	20
S26/0824	10.0	9.7	12.0	0	20	27.0	6.8	42.0	0	20	43.5	41.0	47.1	0	20
S26/0846	3.3	3.0	3.7	0	21	11.0	2.8	22.0	0	21	29.0	26.0	31.0	0	21
S27/0009	9.4	8.6	10.4	0	20	23.5	11.0	36.2	0	20	42.0	39.0	49.1	0	20
S27/0070	3.8	3.5	5.4	0	19	13.0	7.8	24.4	5	19	22.0	19.9	44.8	0	19
S27/0136	11.0	7.6	13.2	0	19	21.0	12.7	34.6	0	19	33.0	18.6	47.3	0	19
S27/0156	2.0	1.8	2.4	0	19	11.0	5.9	17.1	0	19	30.0	26.9	32.2	0	19
S27/0202	13.0	10.8	16.0	0	20	26.5	7.0	41.6	0	20	33.5	28.0	40.0	0	20
S27/0268	<0.5	<0.5	<0.5	100	20	48.5	34.2	73.6	0	20	230.0	190.0	240.5	0	20
S27/0283	0.6	0.2	1.7	65	17	33.0	15.6	45.4	0	17	59.0	54.8	67.2	0	17
S27/0299	4.1	3.8	4.3	0	20	10.0	4.3	19.1	0	20	28.0	26.0	30.0	0	20
S27/0344	10.0	9.4	11.8	0	18	32.5	15.8	43.4	0	18	72.5	65.0	78.3	0	18
S27/0389	4.9	4.2	5.7	0	20	8.0	5.4	11.1	0	20	39.0	34.0	41.1	0	20
S27/0396	31.3	22.3	36.1	0	19	32.0	21.0	56.4	0	19	220.0	155.0	239.5	0	19
S27/0433	<0.5	<0.5	<0.5	100	19	65.0	46.7	93.7	0	19	219.0	188.0	230.2	0	19
S27/0435	<0.5	<0.5	<0.5	100	20	29.0	20.9	44.8	0	20	62.0	53.8	66.0	0	20
S27/0442	<0.5	<0.5	<0.5	100	20	8.4	6.0	12.1	0	20	31.5	27.9	34.1	0	20
S27/0495	<0.5	<0.5	<0.5	100	19	29.0	18.4	38.5	0	19	130.0	109.0	173.4	0	19
S27/0522	35.3	34.0	41.9	0	20	32.0	22.8	40.1	0	20	151.5	130.0	165.0	0	20
S27/0571	7.8	7.0	11.1	0	20	13.0	8.0	18.2	0	20	58.5	53.0	65.2	0	20
S27/0585	1.4	0.6	1.9	11	19	33.0	18.9	53.0	0	19	94.0	86.6	100.3	0	19

Site number	Sulphate (mg/L)					Free CO_2 (mg/L at 25°C)					Total hardness (mg/L as $CaCO_3$)				
	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*	Median	5% percentile	95% percentile	% of censored values	*n*
S27/0588	8.7	7.9	9.3	0	20	13.5	8.0	23.2	5	20	41.0	39.0	43.1	0	20
S27/0594	<0.5	<0.5	<0.5	100	17	10.0	6.2	17.4	0	17	137.0	129.6	145.2	0	17
S27/0602	<0.5	<0.5	<0.5	100	19	17.0	12.7	25.9	0	19	90.0	80.1	98.4	0	19
S27/0607	0.1	0.0	0.6	89	19	61.0	41.6	79.0	0	19	220.0	136.3	242.6	0	19
S27/0614	4.9	3.8	12.7	0	21	23.0	16.0	37.0	0	21	85.0	61.0	98.0	0	21
S27/0615	17.0	14.1	25.9	0	21	22.0	13.0	36.0	0	21	69.0	49.0	78.0	0	21
S27/0681	24.1	19.0	32.9	0	19	22.0	14.9	33.0	0	19	160.0	147.4	191.2	0	19
T26/0003	5.2	4.0	7.3	0	20	14.5	6.4	24.8	0	20	23.0	17.0	36.0	0	20
T26/0087	4.4	3.1	5.8	0	20	17.0	4.3	37.1	0	20	36.0	31.0	42.0	0	20
T26/0099	8.8	7.4	9.5	0	20	13.5	3.0	22.5	0	20	43.5	37.9	50.0	0	20
T26/0206	1.9	1.6	2.2	0	20	5.0	2.0	9.9	0	20	39.5	36.0	43.1	0	20
T26/0259	5.7	4.9	8.1	0	20	12.0	5.0	31.3	0	20	27.0	22.0	38.5	0	20
T26/0332	12.5	11.4	13.1	0	20	44.5	22.6	59.3	0	20	48.5	45.0	53.0	0	20
T26/0413	0.7	0.5	1.0	20	20	9.1	4.0	17.2	0	20	54.0	50.9	59.0	0	20
T26/0430	5.4	4.4	7.1	0	20	21.0	11.7	33.1	0	20	32.5	25.0	40.4	0	20
T26/0489	11.9	10.3	13.2	5	20	33.5	15.8	57.8	0	20	88.0	80.7	92.2	0	20
T26/0538	40.5	38.9	49.3	0	20	47.5	14.7	77.6	0	20	117.5	104.8	140.0	0	20
Riversdale															
T27/0063	18.0	10.5	23.6	0	9	9.4	7.8	14.6	0	9	220.0	188.0	258.0	0	9

Site no.	Faecal coliforms* (cfu/100mL)				
	Median	Minimum	Maximum	% of censored values	*n*
Kapiti Coast					
R25/5100	<1	<1	1	95	20
R25/5164	37	<1	3,000	16	19
R25/5165	<1	<1	<1	100	19
R25/5190	<1	<1	3	95	20
R25/5233	<1	<1	<1	100	20
R26/6587	<1	<1	<1	100	17
R26/6624	<1	<1	<10	100	19
S25/5125	<1	<1	<4	100	21
S25/5200	<1	<1	<1	100	18
S25/5322	<1	<1	<4	100	21
Hutt Valley					
R27/1137	<1	<1	6	80	20
R27/1183	<1	<1	3	95	20
R27/6833	<1	<1	<4	100	20
Wainuiomata					
R27/6418	<1	<1	100	74	20
Wairarapa Valley					
S26/0117	<1	<1	80	63	19
S26/0223	<1	<1	5	90	20
S26/0299	<1	<1	22	95	19
S26/0439	<1	<1	840	95	19
S26/0457	<1	<1	<1	100	18
S26/0467	<1	<1	3	95	19
S26/0705	<1	<1	1	94	17
S26/0762	<1	<1	12	90	20
S26/0824	<1	<1	<1	100	18
S27/0009	<1	<1	5	90	20
S27/0070	<1	<1	1	95	19

Site no.	Faecal coliforms* (cfu/100mL)				
	Median	Minimum	Maximum	% of censored values	*n*
S27/0136	<1	<1	52	58	19
S27/0156	<1	<1	100	89	19
S27/0202	<1	<1	800	60	20
S27/0299	<1	<1	<1	100	18
S27/0344	<1	<1	<1	94	16
S27/0389	<1	<1	34	95	20
S27/0396	<1	<1	<4	100	19
S27/0522	<1	<1	<4	100	20
S27/0571	<1	<1	<4	100	19
S27/0588	<1	<1	<1	100	19
S27/0681	<1	<1	4	84	19
T26/0003	<1	<1	1	90	20
T26/0099	<1	<1	1	95	20
T26/0206	<1	<1	1	100	20
T26/0259	<1	<1	1	100	20
T26/0332	<1	<1	1	100	19
T26/0430	<1	<1	20	70	20
T26/0538	<1	<1	1	95	20
Riversdale					
T27/0063	<1	<1	5	95	19

* Faecal coliforms are only tested in 44 bores.

Appendix 5: Canadian water quality index – background

Information on the calculations behind the Canadian WQI are outlined below, drawn on material from CCME (2001). These calculations were applied to GQSoE data collected at quarterly intervals between August 2005 and July 2010 (see Section 4.3). The Drinking WQI and Aquatic Ecosystems WQI scores for each GQSoE bore are summarised in Table A5.1.

The Canadian WQI is based on three elements:

- *Scope*: the number of variables that do not meet the assigned compliance thresholds (known as the *objectives*) on at least one sampling occasion.

- *Frequency*: the frequency with which individual sample results fail to meet the assigned compliance thresholds.

- *Magnitude*: the amount by which individual sample results fail to meet the assigned compliance thresholds.

Calculation of water quality indices:

F_1 (Scope) represents the percentage of variables that do not meet their objectives at least once during the time period under consideration (‘failed variables’), relative to the total number of variables measured:

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}}\right) \times 100$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives (‘failed tests’):

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}}\right) \times 100$$

F_3 (Magnitude) represents the amount by which ‘failed’ test values do not meet objectives. F_3 is calculated in three steps.

i) The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an ‘excursion’ and is expressed as follows. When the test value must not exceed the objective:

$$\text{excursions}_i = \left(\frac{\text{Failed test value}_i}{\text{Objective}_j}\right) - 1$$

For the cases in which the test value must not fall below the objective:

$$\text{excursions}_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}_i}\right)\text{-1}$$

ii) The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as the normalised sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} \text{excursions}_i}{\#\text{ of tests}}$$

iii) F_3 is then calculated by an asymptotic function that scales the normalised sum of the excursions from objectives (*nse*) to yield a range between 0 and 100.

$$F_3 = \left(\frac{\text{nse}}{0.01\,\text{nse} + 0.01}\right)$$

Once the factors have been obtained, the index itself can be calculated by summing the three factors as if they were vectors. The sum of the squares of each factor is therefore equal to the square of the index. This approach treats the index as a three-dimensional space defined by each factor along one axis. With this model, the index changes in direct proportion to changes in all three factors.

The CCME Water Quality Index (CCME WQI):

$$\text{CCME WQI} = 100 - \left(\frac{\sqrt{F_1^{\,2} + F_2^{\,2} + F_3^{\,2}}}{1.732}\right)$$

The divisor 1.732 normalises the resultant values to a range between 0 and 100, where 0 represents the ‘worst’ water quality and 100 represents the ‘best’ water quality.

Table A5.1: Drinking WQI and Aquatic Ecosystem WQI scores for 71 GQSoE bores sampled quarterly between August 2005 and July 2010. See Section 4.3 for the list of water quality variables used in each WQI.

Bore no.	Drinking WQI	Aquatic Ecosystems WQI	Bore no.	Drinking WQI	Aquatic Ecosystems WQI
R25/5100	67.4	47.8	S27/0070	91.9	88.4
R25/5135	76.2	77.8	S27/0136	81.1	68.6
R25/5164	43.4	41.4	S27/0156	78.0	84.6
R25/5165	72.0	82.6	S27/0202	58.1	65.9
R25/5190	92.1	67.7	S27/0268	55.2	71.1
R25/5233	95.1	76.3	S27/0283	54.6	75.1
R26/6503	89.9	85.5	S27/0299	95.6	88.4
R26/6587	94.9	86.2	S27/0344	78.1	80.6
R26/6624	91.8	65.5	S27/0389	87.2	88.2
R27/0320	96.4	88.2	S27/0396	92.2	73.8
R27/1137	87.4	71.2	S27/0433	46.5	55.5
R27/1171	80.7	87.3	S27/0435	53.0	54.6
R27/1180	94.8	73.1	S27/0442	84.1	68.1
R27/1182	90.9	55.0	S27/0495	57.9	58.8
R27/1183	91.8	88.4	S27/0522	91.9	54.7
R27/1265	91.6	88.3	S27/0571	95.3	56.4
R27/6418	86.5	70.3	S27/0585	66.4	85.0
R27/6833	92.1	72.4	S27/0588	64.4	100.0
S25/5125	94.9	72.7	S27/0594	79.0	100.0
S25/5200	81.3	80.3	S27/0602	64.0	77.5
S25/5256	94.8	45.2	S27/0607	42.7	50.5
S25/5322	91.9	60.8	S27/0614	62.8	71.0
S26/0117	81.1	69.1	S27/0615	52.9	76.6
S26/0223	88.3	59.8	S27/0681	89.1	75.9
S26/0299	90.8	69.7	T26/0003	91.8	74.9
S26/0439	57.2	63.0	T26/0087	95.3	72.3
S26/0457	94.9	85.9	T26/0099	91.9	75.7
S26/0467	91.8	71.4	T26/0206	100.0	76.8
S26/0568	65.8	100.0	T26/0259	95.0	75.8
S26/0576	75.6	87.0	T26/0332	87.0	88.1
S26/0705	91.8	65.9	T26/0413	91.6	83.7
S26/0756	67.5	82.7	T26/0430	90.6	87.2
S26/0762	55.2	100.0	T26/0489	91.6	47.0
S26/0824	95.1	67.0	T26/0538	81.3	59.8
S26/0846	92.3	100.0	T27/0063	92.2	81.7
S27/0009	91.7	71.8			

Appendix 6: Temporal trend results

Table A6.1: Temporal trends in 10 groundwater quality variables measured quarterly in 71 GQSoE bores over August 2005 to July 2010 using the Mann-Kendall or Seasonal Kendall test (grey shading indicates where the Seasonal Kendall test was used) and Sen's slope estimator. Statistically significant (*p*<0.05) and environmentally meaningful (statistically significant and a relative rate of change >5 %/year or absolute rate of change for nitrate >0.1 mg/L) trends are shown in bold font.

Total Dissolved Solids (TDS), mg/L						
Bore no.	*n*	% censored values	Median	*p*-value	Median annual Sen slope	Relative rate of change (%/year)
Kapiti Coast						
R25/5100	20	0	210	**0.0194**	-2.86	-1.36
R25/5135	19	0	342	0.1734	1.68	0.49
R25/5164	19	0	120	0.5980	1.75	1.46
R25/5165	19	0	130	**0.0001**	-15.43	**-11.87**
R25/5190	20	0	210	0.5138	-1.72	-0.817
R25/5233	20	0	96	0.6959	0.61	0.64
R26/6503	20	0	177.5	**0.0158**	-6.28	-3.54
R26/6587	17	0	84	**0.0314**	-2.83	-3.37
R26/6624	19	0	150	0.0959	-2.16	-1.44
S25/5125	21	0	87	0.2624	-2.39	-2.75
S25/5200	18	0	180	**0.0498**	-1.24	-0.69
S25/5256	19	0	170	**0.0004**	-5.89	-3.47
S25/5322	21	0	246	0.1027	-2.82	-1.14
Hutt Valley						
R27/0320	20	0	120	0.6175	0	0
R27/1137	20	0	72.5	0.0551	3.93	5.43
R27/1171	16	0	95.5	0.2887	-0.54	-0.56
R27/1180	20	0	89.5	0.7440	0.25	0.28
R27/1182	20	0	123	0.2906	1.05	0.86
R27/1183	20	0	61	0.3953	0.60	0.98
R27/1265	20	0	77.5	0.2164	-1.74	-2.25
R27/6833	20	0	120	0.5328	0.53	0.44
Wainuiomata						
R27/6418	20	0	111.5	0.1326	-3.44	-3.08
Wairarapa Valley						
S26/0117	20	0	97.5	0.8199	-0.83	-0.85
S26/0223	20	0	140	0.4342	-3.18	-2.27
S26/0299	19	0	78	0.8062	-0.80	-1.02
S26/0439	20	0	113	0.0521	-3.33	-2.95
S26/0457	18	0	50	0.9092	0	0
S26/0467	20	0	89	0.9740	0	0
S26/0568	20	0	173.5	0.1208	1.62	0.93
S26/0576	18	0	150	0.4010	1.89	1.26
S26/0705	20	0	120	0.8940	0	0
S26/0756	18	0	177	0.1020	-2.99	-1.69
S26/0762	20	0	200	0.8447	0	0
S26/0824	20	0	123.5	0.6458	-0.18	-0.15
S26/0846	21	0	61	0.6718	-0.45	-0.74
S27/0009	20	0	110	1	0	0
S27/0070	19	0	49	0.7002	1.00	2.05
S27/0136	19	0	100	0.0581	-6.43	-6.43
S27/0156	19	0	100	0.6210	-0.58	-0.58
S27/0202	20	0	98.5	0.8191	0	0
S27/0268	20	0	350	1	0	0
S27/0283	17	0	180	0.1247	-3.03	-1.69
S27/0299	20	0	62.5	0.7940	-0.18	-0.30
S27/0344	18	0	190	0.2710	3.54	1.86
S27/0389	20	0	140	0.5994	0.43	0.30

Total Dissolved Solids (TDS), mg/L						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
S27/0396	19	0	310	0.2316	-4.07	-1.31
S27/0433	19	0	435	0.7770	0	0
S27/0435	20	0	211.5	0.6703	-0.24	-0.112
S27/0442	20	0	370	0.7186	0	0
S27/0495	19	0	376	**0.0001**	-23.24	**-6.18**
S27/0522	20	0	440	0.2277	-4.27	-0.97
S27/0571	20	0	185	**0.0336**	4.07	2.20
S27/0585	19	0	270	0.6742	0	0
S27/0588	20	0	110	0.6617	0	0
S27/0594	17	0	310	0.1151	1.94	0.63
S27/0602	19	0	260	0.9152	0	0
S27/0607	19	0	760	**0.0204**	-27.78	-3.65
S27/0614	21	0	270	0.8572	0.00	0.00
S27/0615	21	0	215	**0.0004**	7.96	3.70
S27/0681	19	0	255	1	0	0
T26/0003	20	0	61.5	0.4742	-1.43	-2.33
T26/0087	20	0	83	0.7202	-0.48	-0.58
T26/0099	20	0	110	0.0671	-4.67	-4.25
T26/0206	20	0	100	1	0	0
T26/0259	20	0	58.5	0.8452	0.32	0.55
T26/0332	20	0	150	0.3730	0.97	0.65
T26/0413	20	0	110	0.5786	0.38	0.35
T26/0430	20	0	69	0.4343	-1.16	-1.68
T26/0489	20	0	210	0.0651	0.69	0.33
T26/0538	20	0	240	0.0736	4.50	1.88
Riversdale						
T27/0063	9	0	350	0.3428	-23.32	-6.66

Nitrite nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	55	0.002			
R25/5135	19	84.2	0.001			
R25/5164	19	78.9	0.001			
R25/5165	19	57.9	0.001			
R25/5190	20	65	0.001			
R25/5233	20	100	0.001			
R26/6503	20	90	0.001			
R26/6587	17	94.1	0.001			
R26/6624	19	100	0.001			
S25/5125	21	100	0.001			
S25/5200	18	94.4	0.001			
S25/5256	19	100	0.001			
S25/5322	21	95.2	0.001			
Hutt Valley						
R27/0320	20	85	0.001			
R27/1137	20	70	0.001			
R27/1171	16	93.8	0.001			
R27/1180	20	95	0.001			
R27/1182	20	0	0.010	0.0590	0.0003	2.90
R27/1183	20	100	0.001			
R27/1265	20	90	0.001			
R27/6833	20	75	0.001			
Wainuiomata						
R27/6418	20	100	0.001			

Nitrite nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Wairarapa Valley						
S26/0117	20	90	0.001			
S26/0223	20	100	0.001			
S26/0299	19	94.7	0.001			
S26/0439	20	100	0.001			
S26/0457	18	100	0.001			
S26/0467	20	90	0.001			
S26/0568	20	15	0.004	0.1713	0.0004	10.01
S26/0576	18	83.3	0.001			
S26/0705	20	90	0.001			
S26/0756	18	5.6	0.004	0.1092	-0.0004	-9.75
S26/0762	20	20	0.006	0.3704	0.0004	0.00
S26/0824	20	100	0.001			
S26/0846	21	95.2	0.001			
S27/0009	20	95	0.001			
S27/0070	19	100	0.001			
S27/0136	19	47.4	0.002			
S27/0156	19	94.7	0.001			
S27/0202	20	100	0.001			
S27/0268	20	80	0.001			
S27/0283	17	5.9	0.014	0.3636	0.0022	15.4
S27/0299	20	90	0.001			
S27/0344	18	77.8	0.001			
S27/0389	20	85	0.001			
S27/0396	19	89.5	0.001			
S27/0433	19	68.4	0.005			
S27/0435	20	85	0.001			
S27/0442	20	100	0.001			
S27/0495	19	52.6	0.005			
S27/0522	20	85	0.001			
S27/0571	20	95	0.001			
S27/0585	19	36.8	0.003			
S27/0588	20	30	0.005	0.2917	-0.0003	-6.1
S27/0594	17	82.4	0.001			
S27/0602	19	94.7	0.001			
S27/0607	18	50	0.003			
S27/0614	21	47.6	0.005			
S27/0615	21	38.1	0.005			
S27/0681	19	94.7	0.001			
T26/0003	20	95	0.001			
T26/0087	20	90	0.001			
T26/0099	20	95	0.001			
T26/0206	20	0	0.017	**0.0429**	0.0006	3.6
T26/0259	20	95	0.001			
T26/0332	20	0	0.006	**0.0033**	0.0006	**10.9**
T26/0413	20	90	0.001			
T26/0430	20	90	0.001			
T26/0489	20	80	0.001			
T26/0538	20	90	0.001			
Riversdale						
T27/0063	19	89.5	0.001			

Nitrate nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	80	0.001			
R25/5135	19	68.4	0.001			

Nitrate nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
R25/5164	19	0	0.410	0.1952	0.0366	8.92
R25/5165	19	5.3	0.016	0.1952	-0.0048	-30.04
R25/5190	20	0	5.09	0.7701	-0.1699	-3.34
R25/5233	20	0	1.60	0.3968	0.0598	3.74
R26/6503	20	0	0.019	0.1728	0.0137	74.12
R26/6587	17	0	0.670	0.3434	0.0391	5.84
R26/6624	19	0	2.90	0.3261	-0.0833	-2.87
S25/5125	21	0	2.60	0.7167	-0.0532	-2.05
S25/5200	18	50	0.002			
S25/5256	19	0	9.60	**0.0299**	**-0.2766**	-2.88
S25/5322	21	0	9.90	0.7843	0	0
Hutt Valley						
R27/0320	20	55	0.001			
R27/1137	20	5	1.04	**0.0273**	0.1998	19.22
R27/1171	16	81.3	0.001			
R27/1180	20	0	0.849	0.0638	0.0332	3.92
R27/1182	20	0	0.801	0.6031	0.0045	0.56
R27/1183	20	0	0.313	0.8489	0.0042	1.34
R27/1265	20	5	0.200	0.1616	-0.0044	-2.19
R27/6833	20	0	0.571	0.5692	-0.0331	-5.80
Wainuiomata						
R27/6418	20	0	1.74	0.8481	0.0038	0.22
Wairarapa Valley						
S26/0117	20	0	3.40	0.6963	0.0659	1.94
S26/0223	20	0	9.15	0.3987	-0.3210	-3.51
S26/0299	19	0	2.70	**0.0356**	-0.3128	**-11.58**
S26/0439	20	0	3.50	0.3434	-0.0201	-0.58
S26/0457	18	0	0.432	0.1393	-0.0383	-8.88
S26/0467	20	0	2.00	0.0852	-0.2226	-11.13
S26/0568	20	75	0.001			
S26/0576	18	66.7	0.001			
S26/0705	20	0	4.84	0.2379	-0.0092	-0.19
S26/0756	18	33.3	0.004			
S26/0762	20	25	0.003	0.4921	-0.0002	-6.01
S26/0824	20	0	5.30	**0.0035**	**-0.1772**	-3.34
S26/0846	21	0	0.658	0.8326	-0.0044	-0.67
S27/0009	20	0	2.95	1	0	0
S27/0070	19	0	0.454	0.6824	0.0102	2.26
S27/0136	19	0	5.42	**0.0157**	-0.6848	**-12.64**
S27/0156	19	36.8	0.003			
S27/0202	20	0	3.52	0.2053	-0.2069	-5.88
S27/0268	20	55	0.003			
S27/0283	17	52.9	0.002			
S27/0299	20	0	0.265	**0.0000**	0.0188	**7.11**
S27/0344	18	27.8	0.003	0.0514	-0.0004	-11.82
S27/0389	20	60	0.001			
S27/0396	19	0	0.218	0.8383	0.0082	3.74
S27/0433	19	73.7	0.003			
S27/0435	20	80	0.001			
S27/0442	20	90	0.001			
S27/0495	19	52.6	0.004			
S27/0522	20	0	3.28	0.6242	-0.0144	-0.44
S27/0571	20	0	9.22	1.0000	-0.0075	-0.08
S27/0585	19	73.7	0.001			
S27/0588	20	50	0.004			
S27/0594	17	70.6	0.001			
S27/0602	19	78.9	0.001			
S27/0607	18	50	0.005			
S27/0614	21	66.7	0.003			
S27/0615	21	42.9	0.004			

Nitrate nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
S27/0681	19	0	0.212	0.8337	-0.0112	-5.26
T26/0003	20	0	1.87	0.8711	-0.0471	-2.52
T26/0087	20	0	0.980	0.0877	0.1444	14.73
T26/0099	20	0	5.60	**0.0016**	-0.5173	**-9.24**
T26/0206	20	0	1.52	**0.0242**	0.0651	4.28
T26/0259	20	0	1.03	0.7946	-0.0192	-1.86
T26/0332	20	0	0.745	0.4555	-0.0204	-2.74
T26/0413	20	85	0.001			
T26/0430	20	0	1.49	0.6495	0.0422	2.84
T26/0489	20	0	11.00	0.8963	0	0
T26/0538	20	0	10.05	**0.0158**	**-0.3423**	-3.41
Riversdale						
T27/0063	19	0	2.33	0.3558	-0.7103	-30.48

Ammoniacal nitrogen (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	0	0.18	**0.0168**	-0.0050	-2.87
R25/5135	19	0	0.29	0.5668	0	0
R25/5164	19	36.8	0.01			
R25/5165	19	0	0.24	**0.0003**	-0.0285	**-11.86**
R25/5190	20	20	0.03	0.7190	-0.0003	-0.99
R25/5233	20	85	0.01			
R26/6503	20	60	0.01			
R26/6587	17	76.5	0.01			
R26/6624	19	78.9	0.01			
S25/5125	21	90.5	0.01			
S25/5200	18	0	0.02	0.9076	0	0
S25/5256	19	89.5	0.01			
S25/5322	21	81.0	0.01			
Hutt Valley						
R27/0320	20	0	0.12	0.3277	0	0
R27/1137	20	80	0.01			
R27/1171	16	0	0.34	0.1092	-0.0097	-2.90
R27/1180	20	85	0.01			
R27/1182	20	75	0.01			
R27/1183	20	90	0.01			
R27/1265	20	55	0.01			
R27/6833	20	75	0.01			
Wainuiomata						
R27/6418	20	75	0.01			
Wairarapa Valley						
S26/0117	20	80	0.01			
S26/0223	20	70	0.01			
S26/0299	19	94.7	0.01			
S26/0439	20	95	0.01			
S26/0457	18	94.4	0.01			
S26/0467	20	95	0.01			
S26/0568	20	0	0.44	0.8695	0	0
S26/0576	18	0	0.37	0.2600	0.00484081	1.326249315
S26/0705	20	80	0.01			
S26/0756	18	0	0.08	0.09054704	-0.0075476	-9.4345
S26/0762	20	0	0.51	0.6449	0	0
S26/0824	20	80	0.01			
S26/0846	21	76.2	0.01			
S27/0009	20	90	0.01			

Ammoniacal nitrogen (mg/L)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
S27/0070	19	94.7	0.01			
S27/0136	19	42.1	0.01			
S27/0156	19	15.8	0.02	0.6982	0.0006	3.64
S27/0202	20	80	0.01			
S27/0268	20	0	0.97	0.9481	0	0
S27/0283	17	0	0.88	0.3426	-0.0159	-1.81
S27/0299	20	75	0.01			
S27/0344	18	0	0.08	0.2491	-0.0022	-2.62
S27/0389	20	0	0.12	0.1857	-0.0076	-6.34
S27/0396	19	73.7	0.01			
S27/0433	19	0	7.30	0.4836	0.0666	0.91
S27/0435	20	0	7.90	0.0595	0.1074	1.36
S27/0442	20	0	0.94	0.4931	-0.0083	-0.88
S27/0495	19	0	1.90	**0.0016**	-0.0923	-4.86
S27/0522	20	80	0.01			
S27/0571	20	85	0.01			
S27/0585	19	0	0.63	0.1335	-0.0303	-4.82
S27/0588	20	0	0.09	**0.0017**	-0.0048	**-5.38**
S27/0594	17	0	0.73	0.9339	0	0
S27/0602	19	0	2.60	0.1893	-0.0192	-0.74
S27/0607	19	0	10.20	1.0000	0.0000	0.00
S27/0614	21	0	0.78	0.2159	-0.0182	-2.33
S27/0615	21	0	0.52	0.8569	0	0
S27/0681	19	78.9	0.01			
T26/0003	20	85	0.01			
T26/0087	20	85	0.01			
T26/0099	20	90	0.01			
T26/0206	20	90	0.01			
T26/0259	20	80	0.01			
T26/0332	20	65	0.01			
T26/0413	20	0	0.05	0.8481	-0.00037784	-0.779051546
T26/0430	20	85	0.01			
T26/0489	20	90	0.01			
T26/0538	20	70	0.01			
Riversdale						
T27/0063	19	84.2	0.01			

Dissolved iron (mg/L)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	0	1.59	0.3810	0.1672	10.52
R25/5135	19	0	0.80	0.3446	0.0256	3.20
R25/5164	19	31.6	0.03			
R25/5165	19	0	2.89	**0.0003**	-0.3534	**-12.23**
R25/5190	20	100	0.01			
R25/5233	20	100	0.01			
R26/6503	20	35	0.07			
R26/6587	17	52.9	0.01			
R26/6624	19	94.7	0.01			
S25/5125	21	95.2	0.01			
S25/5200	18	0	0.59	0.3633	-0.0350	-5.98
S25/5256	19	78.9	0.01			
S25/5322	21	100	0.01			
Hutt Valley						
R27/0320	20	0	0.09	0.8958	0	0
R27/1137	20	15	0.07	**0.0077**	0.0340	**48.20**
R27/1171	16	0	1.25	**0.0296**	-0.0364	-2.93

Dissolved iron (mg/L)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
R27/1180	20	100	0.01			
R27/1182	20	0	0.19	0.6244	0.0040	2.17
R27/1183	20	90	0.01			
R27/1265	20	0	0.19	0.1265	0.0182	9.82
R27/6833	20	75	0.01			
Wainuiomata						
R27/6418	20	90	0.01			
Wairarapa Valley						
S26/0117	20	100	0.01			
S26/0223	20	100	0.01			
S26/0299	19	100	0.01			
S26/0439	20	70	0.01			
S26/0457	18	100	0.01			
S26/0467	20	100	0.01			
S26/0568	20	0	3.50	0.2283	-0.0503	-1.44
S26/0576	18	0	1.35	0.7326	0.0224	1.66
S26/0705	20	85	0.01			
S26/0756	18	0	2.65	**0.0302**	-0.1503	**-5.67**
S26/0762	20	0	7.48	0.7212	0.0552	0.74
S26/0824	20	90	0.01			
S26/0846	21	14.3	0.04	0.4860	0.0030	8.56
S27/0009	20	90	0.01			
S27/0070	19	84.2	0.01			
S27/0136	19	15.8	0.04	0.4389	0.0034	8.38
S27/0156	19	0	0.35	1.0000	0	0
S27/0202	20	95	0.01			
S27/0268	20	0	6.85	0.1443	-0.2399	-3.50
S27/0283	17	0	8.11	0.1371	-0.2143	-2.64
S27/0299	20	20	0.03	0.2624	-0.0021	-6.93
S27/0344	18	0	0.93	0.1965	0.0202	2.18
S27/0389	20	10	0.11	0.3800	-0.0116	-10.55
S27/0396	19	15.8	0.04	0.5040	-0.0028	-6.97
S27/0433	19	0	12.60	0.0971	-0.3104	-2.46
S27/0435	20	0	6.55	0.1528	-0.1733	-2.65
S27/0442	20	0	1.17	**0.0094**	-0.1466	**-12.59**
S27/0495	19	0	4.90	**0.0002**	-0.5798	**-11.83**
S27/0522	20	30	0.02	**0.0081**	0.0104	**44.04**
S27/0571	20	70	0.01			
S27/0585	19	0	1.44	0.5745	0.0306	2.12
S27/0588	20	0	4.60	0.1174	-0.0520	-1.13
S27/0594	17	0	1.70	1	0	0
S27/0602	19	0	3.30	0.1507	-0.0702	-2.13
S27/0607	19	0	16.00	0.1940	-0.3131	-1.96
S27/0614	21	0	4.40	0.0995	-0.0957	-2.17
S27/0615	21	0	6.90	**0.0028**	0.5656	**8.20**
S27/0681	19	89.5	0.01			
T26/0003	20	95	0.01			
T26/0087	20	35	0.05			
T26/0099	20	100	0.01			
T26/0206	20	100	0.01			
T26/0259	20	100	0.01			
T26/0332	20	100	0.01			
T26/0413	20	0	0.30	**0.0250**	0.0487	**16.52**
T26/0430	20	100	0.01			
T26/0489	20	90	0.01			
T26/0538	20	90	0.01			
Riversdale						
T27/0063	9	100	0.01			

Dissolved manganese (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	0	1.60	**0.0452**	-0.0303	-1.90
R25/5135	19	0	0.860	0.5284	-0.0078	-0.91
R25/5164	19	0	0.011	0.1237	-0.0016	-15.16
R25/5165	19	0	0.085	**0.0000**	-0.0120	**-14.16**
R25/5190	20	0	0.022	1.0000	0.0001	0.39
R25/5233	20	95	0.0003			
R26/6503	20	0	0.013	**0.0047**	0.0034	**25.83**
R26/6587	17	0	0.002	0.4078	-0.0001	-6.09
R26/6624	19	73.7	0.0003			
S25/5125	21	71.4	0.0003			
S25/5200	18	0	0.940	0.3817	-0.0141	-1.50
S25/5256	19	10.5	0.001	0.9452	0	0
S25/5322	21	76.2	0.0003			
Hutt Valley						
R27/0320	20	0	0.063	0.1830	-0.0011	-1.69
R27/1137	20	20	0.004	**0.0022**	0.0026	**60.11**
R27/1171	16	0	0.240	0.2361	-0.0052	-2.17
R27/1180	20	95	0.0003			
R27/1182	20	0	0.057	0.6729	-0.0003	-0.60
R27/1183	20	90	0.0003			
R27/1265	20	0	0.021	**0.0124**	-0.0021	**-10.30**
R27/6833	20	0	0.255	0.7205	-0.0033	-1.30
Wainuiomata						
R27/6418	20	25	0.001	0.8969	0	0
Wairarapa Valley						
S26/0117	20	10	0.001	0.9741	0.0000	-0.57
S26/0223	20	0	0.001	0.7697	0.0000	2.19
S26/0299	19	0	0.002	0.5272	0.0001	3.37
S26/0439	20	0	0.001	0.8483	0.0000	-1.10
S26/0457	18	0	0.001	0.4231	0.0000	1.07
S26/0467	20	20	0.001	0.3704	-0.0001	-6.04
S26/0568	20	0	0.823	0.2550	-0.0095	-1.15
S26/0576	18	0	0.605	0.1393	-0.0091	-1.50
S26/0705	20	30	0.001	**0.0158**	-0.0001	**-16.01**
S26/0756	18	0	0.940	0.0692	-0.0256	-2.72
S26/0762	20	0	0.898	0.7212	-0.0055	-0.62
S26/0824	20	0	0.001	**0.0051**	-0.0002	**-15.62**
S26/0846	21	0	0.004	0.3488	0.0002	5.45
S27/0009	20	50	0.0004			
S27/0070	19	5.3	0.001	0.3440	0.0000	-4.54
S27/0136	19	0	0.016	0.6746	-0.0005	-3.08
S27/0156	19	0	0.332	0.4514	-0.0044	-1.31
S27/0202	20	0	0.002	0.7991	0.0000	-1.76
S27/0268	20	0	1.50	**0.0087**	-0.0536	-3.58
S27/0283	17	0	0.510	**0.0050**	-0.0197	-3.87
S27/0299	20	35	0.001			
S27/0344	18	0	0.476	0.9697	0	0
S27/0389	20	0	0.435	0.1723	-0.0109	-2.50
S27/0396	19	0	0.052	0.2337	-0.0046	-8.77
S27/0433	19	0	1.60	0.0984	-0.0507	-3.17
S27/0435	20	0	0.495	0.4952	-0.0052	-1.05
S27/0442	20	0	0.150	**0.0188**	-0.0046	-3.07
S27/0495	19	0	0.780	**0.0001**	-0.0898	**-11.51**
S27/0522	20	0	0.003	0.2288	0.0006	16.49
S27/0571	20	0	0.004	0.6258	-0.0001	-2.91
S27/0585	19	0	1.40	0.3424	0.0134	0.96
S27/0588	20	0	0.141	0.1141	-0.0019	-1.33
S27/0594	17	0	0.250	0.5863	-0.0017	-0.70
S27/0602	19	0	0.597	**0.0170**	-0.0196	-3.29
S27/0607	19	0	1.40	**0.0330**	-0.0728	**-5.20**
S27/0614	21	0	0.697	0.1768	-0.0182	-2.61
S27/0615	21	0	0.519	**0.0037**	0.0387	**7.45**
S27/0681	19	52.6	0.0003			
T26/0003	20	10	0.001	**0.0294**	0.0001	**19.72**
T26/0087	20	0	0.004	0.3805	0.0007	14.66
T26/0099	20	5	0.002	0.2158	-0.0002	-9.96

Dissolved manganese (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
T26/0206	20	0	0.041	**0.0373**	-0.0014	-3.35
T26/0259	20	80	0.0003			
T26/0332	20	0	1.370	0.5968	0	0
T26/0413	20	0	0.145	0.4470	0.0059	4.04
T26/0430	20	85	0.0003			
T26/0489	20	20	0.001	0.2194	0.0001	10.03
T26/0538	20	0	0.001	**0.0111**	0.0016	**108.60**
Riversdale						
T27/0063	9	88.9	0.0003			

Dissolved lead (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	100	0.0001			
R25/5135	19	84.2	0.0001			
R25/5164	19	0	0.0004	0.2459	-0.00002	-4.87
R25/5165	19	0	0.0010	0.1945	-0.00010	-10.01
R25/5190	20	30	0.0001	0.2458	-0.00001	-12.77
R25/5233	20	20	0.0002	0.5103	0.00000	-3.28
R26/6503	20	70	0.0001			
R26/6587	17	76.5	0.0001			
R26/6624	19	42.1	0.0001			
S25/5125	21	9.5	0.0003	**0.0020**	-0.00013	**-44.20**
S25/5200	18	83.3	0.0001			
S25/5256	19	36.8	0.0001			
S25/5322	21	33.3	0.0002			
Hutt Valley						
R27/0320	20	85	0.0001			
R27/1137	20	70	0.0001			
R27/1171	16	87.5	0.0001			
R27/1180	20	0	0.0007	0.3128	-0.00004	-6.40
R27/1182	20	70	0.0001			
R27/1183	20	0	0.0003	0.5791	-0.00001	-3.23
R27/1265	20	95	0.0001			
R27/6833	20	80	0.0001			
Wainuiomata						
R27/6418	20	5	0.0004	0.1099	0.00010	24.60
Wairarapa Valley						
S26/0117	20	20	0.0002	**0.0002**	0.00010	**60.18**
S26/0223	20	0	0.0004	0.4506	0.00002	5.27
S26/0299	19	0	0.0004	**0.0172**	0.00003	**7.43**
S26/0439	20	15	0.0003	0.4527	0.00003	10.26
S26/0457	18	77.8	0.0001			
S26/0467	20	20	0.0001	**0.0022**	0.00003	**27.54**
S26/0568	20	100	0.0001			
S26/0576	18	100	0.0001			
S26/0705	20	30	0.0002	**0.0001**	-0.00007	**-39.18**
S26/0756	18	94.4	0.0001			
S26/0762	20	95	0.0001			
S26/0824	20	30	0.0002	**0.0083**	-0.00007	**-38.19**
S26/0846	21	95.2	0.0001			
S27/0009	20	85	0.0001			
S27/0070	19	5.3	0.0004	0.4404	-0.00001	-3.64
S27/0136	19	78.9	0.0001			
S27/0156	19	100	0.0001			
S27/0202	20	75	0.0001			
S27/0268	20	85	0.0001			
S27/0283	17	94.1	0.0001			
S27/0299	20	15	0.0003	0.1503	-0.00004	-14.55
S27/0344	18	100	0.0001			
S27/0389	20	90	0.0001			
S27/0396	19	21.1	0.0003	0.7507	0	0

Dissolved lead (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
S27/0433	19	84.2	0.0001			
S27/0435	20	80	0.0001			
S27/0442	20	90	0.0001			
S27/0495	19	100	0.0001			
S27/0522	20	90	0.0001			
S27/0571	20	45	0.0001			
S27/0585	19	89.5	0.0001			
S27/0588	20	95	0.0001			
S27/0594	17	88.2	0.0001			
S27/0602	19	94.7	0.0001			
S27/0607	19	94.7	0.0001			
S27/0614	21	95.2	0.0001			
S27/0615	21	95.2	0.0001			
S27/0681	19	63.2	0.0001			
T26/0003	20	0	0.0002	**0.0016**	0.00003	**16.09**
T26/0087	20	65	0.0001			
T26/0099	20	90	0.0001			
T26/0206	20	95	0.0001			
T26/0259	20	0	0.0002	0.1930	-0.00004	-17.34
T26/0332	20	95	0.0001			
T26/0413	20	95	0.0001			
T26/0430	20	100	0.0001			
T26/0489	20	15	0.0002	0.6026	-0.00003	-10.86
T26/0538	20	80	0.0001			
Riversdale						
T27/0063	9	88.9	0.0001			

Fluoride (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	0	0.13	0.2540	-0.0006	-0.48
R25/5135	19	0	0.09	0.8054	-0.0007	-0.85
R25/5164	19	84.2	0.03			
R25/5165	19	0	0.18	0.2558	0.0035	1.92
R25/5190	20	0	0.09	0.7924	0	0
R25/5233	20	35	0.06			
R26/6503	20	0	0.13	0.5471	0	0
R26/6587	17	11.8	0.07	0.0876	-0.0053	-7.54
R26/6624	19	0	0.17	0.0570	-0.0068	-3.99
S25/5125	21	0	0.09	0.5839	-0.0010	-1.07
S25/5200	18	0	0.25	**0.0057**	-0.0083	-3.40
S25/5256	19	0	0.16	0.7980	0	0
S25/5322	21	0	0.08	0.2210	-0.0016	-2.00
Hutt Valley						
R27/0320	20	0	0.14	0.2100	-0.0011	-0.81
R27/1137	20	20	0.06	0.3585	0.0021	3.55
R27/1171	16	0	0.17	**0.0340**	-0.0087	**-5.11**
R27/1180	20	15	0.06	0.9478	0	0
R27/1182	20	0	0.08	0.8446	0	0
R27/1183	20	10	0.06	0.3947	-0.0014	-2.23
R27/1265	20	0	0.17	0.2905	-0.0037	-2.15
R27/6833	20	0	0.18	0.7150	0	0
Wainuiomata						
R27/6418	20	25	0.06	0.4893	-0.0014	-2.37
Wairarapa Valley						
S26/0117	20	10	0.07	0.0747	-0.0033	-4.74
S26/0223	20	25	0.05	0.7173	0	0
S26/0299	19	68.4	0.03			
S26/0439	20	0	0.10	0.2504	-0.0006	-0.56

Fluoride (mg/L)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
S26/0457	18	55.6	0.03			
S26/0467	20	10	0.07	0.2797	-0.0020	-2.81
S26/0568	20	0	0.11	0.5883	0	0
S26/0576	18	0	0.11	**0.0131**	-0.0075	**-6.85**
S26/0705	20	0	0.15	**0.0433**	-0.0032	-2.13
S26/0756	18	0	0.07	0.1357	-0.0015	0.00
S26/0762	20	0	0.19	0.4024	0	0
S26/0824	20	0	0.12	0.2442	-0.0034	-2.80
S26/0846	21	38.1	0.05			
S27/0009	20	15	0.07	0.9478	0	0
S27/0070	19	73.7	0.03			
S27/0136	19	10.5	0.06	0.1888	0.0030	5.00
S27/0156	19	0	0.24	0.8857	0	0
S27/0202	20	5	0.07	0.8426	0	0
S27/0268	20	10	0.06	0.0898	-0.0042	-6.81
S27/0283	17	0	0.19	0.6597	0	0
S27/0299	20	5	0.08	1	0	0
S27/0344	18	0	0.13	0.1614	-0.0037	-2.81
S27/0389	20	5	0.48	**0.0009**	-0.0136	-2.83
S27/0396	19	0	0.10	**0.0276**	-0.0062	**-6.22**
S27/0433	19	0	0.18	0.1093	-0.0030	-1.64
S27/0435	20	0	0.30	**0.0275**	-0.0065	-2.18
S27/0442	20	0	0.49	**0.0004**	-0.0127	-2.60
S27/0495	19	0	0.18	0.8865	0	0
S27/0522	20	0	0.29	**0.0302**	-0.0070	-2.41
S27/0571	20	0	0.25	**0.0030**	-0.0065	-2.58
S27/0585	19	0	0.54	**0.0001**	-0.0228	-4.21
S27/0588	20	0	0.09	**0.0148**	-0.0040	-4.43
S27/0594	17	0	0.26	0.2246	0	0
S27/0602	19	0	0.20	0.0581	0.0000	0.00
S27/0607	19	0	0.30	0.3752	0.0059	1.97
S27/0614	21	0	0.17	0.1588	-0.0055	-3.25
S27/0615	21	0	0.22	**0.0039**	-0.0097	-4.40
S27/0681	19	0	0.11	**0.0113**	-0.0066	**-5.96**
T26/0003	20	10	0.06	0.3274	0.0024	3.90
T26/0087	20	15	0.06	0.0716	-0.0046	-7.60
T26/0099	20	5	0.09	0.7941	-0.0003	-0.34
T26/0206	20	5	0.08	0.5769	-0.0012	-1.48
T26/0259	20	65	0.03			
T26/0332	20	0	0.23	0.0540	-0.0066	-2.85
T26/0413	20	5	0.09	0.3562	-0.0016	-1.77
T26/0430	20	40	0.05			
T26/0489	20	10	0.06	0.2622	-0.0021	-3.42
T26/0538	20	0	0.11	0.2064	-0.0024	-2.17
Riversdale						
T27/0063	9	11.1	0.06	0.5400	-0.0085	-13.74

Dissolved reactive phosphorus (mg/L)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	10	0.303	0.6261	-0.0019	-0.62
R25/5135	19	0	0.390	**0.0007**	0.0350	**8.98**
R25/5164	19	0	0.182	0.4207	0.0084	4.64
R25/5165	19	0	0.300	**0.0272**	0.0156	**5.19**
R25/5190	20	0	0.089	0.8200	-0.0007	-0.80
R25/5233	20	0	0.013	0.0668	0.0008	6.27
R26/6503	20	50	0.007			

Dissolved reactive phosphorus (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
R26/6587	17	0	0.008	0.1965	0.0004	4.34
R26/6624	19	0	0.021	0.7510	0	0
S25/5125	21	0	0.018	0.1697	0.0005	3.02
S25/5200	18	0	0.136	0.5659	0.0009	0.65
S25/5256	19	0	0.018	**0.0234**	0.0011	**6.30**
S25/5322	21	0	0.048	0.9079	0.0000	0.00
Hutt Valley						
R27/0320	20	0	0.150	0.2924	0.0018	1.21
R27/1137	20	30	0.005	0.2482	-0.0003	-5.45
R27/1171	16	0	0.219	0.1844	0.0034	1.56
R27/1180	20	0	0.012	**0.0376**	0.0007	**5.49**
R27/1182	20	10	0.008	0.4275	0.00005	0.61
R27/1183	20	0	0.009	**0.0024**	0.0008	**8.68**
R27/1265	20	0	0.018	0.1021	-0.0019	-10.83
R27/6833	20	0	0.048	0.3284	0.0010	2.08
Wainuiomata						
R27/6418	20	0	0.016	0.3031	0.0003	1.79
Wairarapa Valley						
S26/0117	20	0	0.016	0.1475	0.0006	3.45
S26/0223	20	0	0.019	0.8183	0	0
S26/0299	19	0	0.021	0.0797	-0.0007	-3.13
S26/0439	20	0	0.024	**0.0107**	-0.0014	**-5.97**
S26/0457	18	0	0.009	0.3045	0.0005	5.39
S26/0467	20	0	0.020	0.5705	0	0
S26/0568	20	0	1.000	0.2053	0.0391	3.91
S26/0576	18	0	0.620	0.4573	-0.0040	-0.65
S26/0705	20	0	0.024	0.2509	-0.0007	-2.83
S26/0756	18	5.6	0.140	0.2110	-0.0132	-9.43
S26/0762	20	0	0.805	1	-0.0005	-0.07
S26/0824	20	0	0.017	0.8947	0	0
S26/0846	21	0	0.020	**0.0350**	-0.0009	-4.49
S27/0009	20	0	0.015	0.3880	-0.0001	-0.79
S27/0070	19	15.8	0.006	0.0662	0.0005	7.94
S27/0136	19	26.3	0.007	0.2281	0.0005	7.03
S27/0156	19	0	0.083	0.4153	0.0013	1.61
S27/0202	20	0	0.021	**0.0107**	-0.0013	**-6.31**
S27/0268	20	75	0.002			
S27/0283	17	23.5	0.213	0.8356	0.0008	0.36
S27/0299	20	0	0.007	0.3267	0.0002	2.62
S27/0344	18	0	0.062	0.1694	-0.0011	-1.72
S27/0389	20	0	0.986	0.8962	0	0
S27/0396	19	0	0.018	0.9720	0	0
S27/0433	19	73.7	0.002			
S27/0435	20	0	4.81	0.8462	0.0000	0.00
S27/0442	20	0	3.90	0.7922	0	0
S27/0495	19	36.8	0.310			
S27/0522	20	60	0.002			
S27/0571	20	0	0.010	0.8686	0	0
S27/0585	19	15.8	0.345	0.2447	-0.0165	-4.77
S27/0588	20	15	0.143	0.1094	0.0087	6.11
S27/0594	17	0	0.520	**0.0229**	0.0860	**16.54**
S27/0602	19	0	1.90	0.9438	0	0
S27/0607	19	36.8	0.009			
S27/0614	21	0	0.537	0.4149	0.0350	6.53
S27/0615	21	4.8	0.273	0.2269	-0.0501	-18.37
S27/0681	19	0	0.014	0.4803	0.0003	2.49
T26/0003	20	0	0.018	0.4725	-0.0005	-2.87
T26/0087	20	0	0.025	**0.0156**	-0.0038	**-15.32**
T26/0099	20	0	0.015	0.3406	0.0004	2.42
T26/0206	20	0	0.064	0.0830	-0.0010	-1.62

Dissolved reactive phosphorus (mg/L)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
T26/0259	20	5	0.007	0.4926	0.0002	3.35
T26/0332	20	0	0.043	0.2658	-0.0006	-1.43
T26/0413	20	0	0.031	**0.0043**	-0.0013	-4.16
T26/0430	20	0	0.013	0.1880	0.0004	3.52
T26/0489	20	0	0.014	0.5259	0	0
T26/0538	20	5	0.007	0.8664	0	0
Riversdale						
T27/0063	19	0	0.076	0.6998	-0.0007	-0.92

*E. coli** (cfu/100mL)						
Bore no.	***n***	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
Kapiti Coast						
R25/5100	20	95	<1			
R25/5164	19	15.8	37	0.2925	13.67	36.95
R25/5165	19	100	<1			
R25/5190	20	95	<1			
R25/5233	20	100	<1			
R26/6587	17	100	<1			
R26/6624	19	100	<1			
S25/5125	21	100	<1			
S25/5200	18	100	<1			
S25/5322	21	100	<1			
Hutt Valley						
R27/1137	20	85	<1			
R27/1183	20	95	<1			
R27/6833	20	100	<1			
Wainuiomata						
R27/6418	19	73.7	<1			
Wairarapa Valley						
S26/0117	19	63.2	<1			
S26/0223	20	90	<1			
S26/0299	19	94.7	<1			
S26/0439	19	94.7	<1			
S26/0457	18	100	<1			
S26/0467	19	94.7	<1			
S26/0705	17	94.1	<1			
S26/0762	20	90	<1			
S26/0824	18	100	<1			
S27/0009	20	90	<1			
S27/0070	19	94.7	<1			
S27/0136	19	63.2	<1			
S27/0156	19	89.5	<1			
S27/0202	20	60	<1			
S27/0299	18	100	<1			
S27/0344	16	93.8	<1			
S27/0389	20	95	<1			
S27/0396	19	100	<1			
S27/0522	20	100	<1			
S27/0571	19	100	<1			
S27/0588	19	100	<1			
S27/0681	19	84.2	<1			
T26/0003	20	90	<1			
T26/0099	20	95	<1			
T26/0206	20	100	<1			
T26/0259	20	100	<1			
T26/0332	19	100	<1			

*E. coli** (cfu/100mL)						
Bore no.	*n*	**% censored values**	**Median**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/year)**
T26/0430	20	70	<1			
T26/0538	20	95	<1			
Riversdale						
T27/0063	19	95.2	<1			

* Only 44 bores are tested for *E. coli*.

Water, air, earth and energy – elements in Greater Wellington's logo that combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community

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