greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Groundwater Nitrate Trend Analysis Report

For data collected between 2003 and 2016

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Executive summary

This report presents the findings of a trend analysis undertaken on nitrate-nitrogen results collected as part of Greater Wellington Regional Council's (GWRC) Groundwater Quality State of the Environment (GQSoE) monitoring programme.

Of the 46 sites analysed, a total of three had increasing concentrations of nitrate (meaningful deteriorating trends) and 11 had decreasing concentrations of nitrate (meaningful improving trends). Overall, several common themes were observed in the trend data:

- Increased pastoral based farming (dairy, sheep and beef) appears to result in increased groundwater nitrate-nitrogen concentrations
- The conversion of pastoral farming operations (dairy, sheep and beef) to lifestyle and/or viticulture results in a decrease in nitrate-nitrogen concentrations in groundwater
- In a single case, the replacement of septic tanks with a reticulated wastewater scheme appears to be leading to improvements in groundwater quality
- Groundwater reacts differently to land use (or drainage) depending on a number of factors including soil type, depth of vadose zone, recharge volume, mean residence time, aquifer geochemistry and aquifer hydraulic properties. As such, the same land use change across two different capture zones may not necessarily result in the same response.
- Determining the cause of a trend in groundwater is complex, as there are multiple factors influencing the cause

The analysis has highlighted that the occurrence and distribution of trends is complex and not all monitoring sites are directly comparable to each other. There needs to be further investigations completed to assess the representativeness of the spatial distribution of the current GWQ monitoring network to determine how well it represents the relative distribution of land uses across the region. There also needs to be further work to align the findings of this report with trends observed in surface water quality results.

Contents

1. Introduction

This report presents the trend analysis of nitrate-nitrogen results collected as part of Greater Wellington Regional Council's (GWRC) Groundwater Quality State of the Environment (GQSoE) monitoring programme. The GQSoE programme incorporates quarterly monitoring of water quality in approximately 71 wells across the Wellington Region. The data analysed as part of this report covers the period October 2003 to 30 June 2016.

2. 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, with differences in the suite of water quality variables and analytical methods. From late 2003, management practices were aligned to provide consistency in sampling methods, sampling frequency (increased from six-monthly to quarterly), analysis and reporting.

Given this, the date range selected for analysis in this report is the period October 2003 to 30 June 2016.

2.1 Monitoring objectives

The aims of GWRC's GQSoE monitoring programme are to:

1. Provide information on the baseline quality of groundwater;
2. Describe the current state of the region's groundwater resources at a regional scale;
3. Assist in the detection of spatial and temporal changes in groundwater quality;
4. Recommend the suitability of groundwater for designated uses; and
5. Provide a mechanism to determine the effectiveness of regional policies and plans.

2.2 Monitoring network

The existing GQSoE monitoring network consists of 71 wells (Figure 1.1, Appendix A). Sites are monitored quarterly, though in any given year there will be occasions when a sample cannot be collected, typically due to restricted access, pump/electrical problems etc.

The GQSoE monitoring wells are spread across four of the five Whaitua (GWRC identified water management areas). The distribution of sites is primarily based on historical groundwater use and resource availability; as a result of this they are not evenly distributed. The number of sites located in each Whaitua is:

- Ruamahanga – 48
- Kapiti Coast – 14
- Wellington and Hutt Valley – 8
- Wairarapa Coast - 1
- Porirua - 0

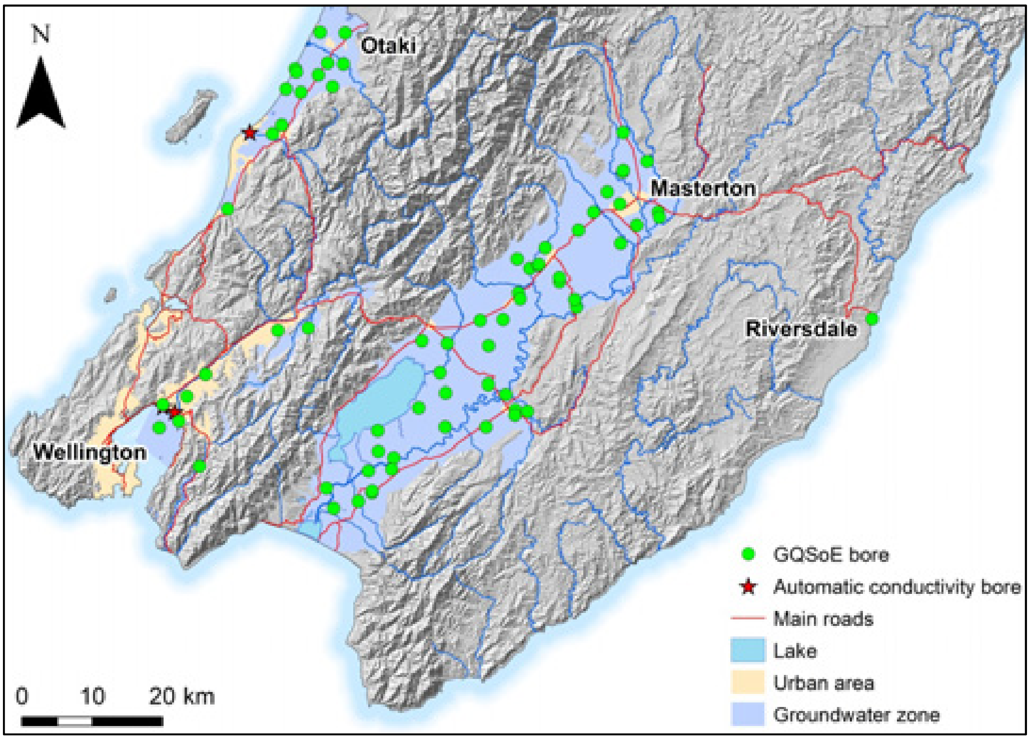


Figure 1.1: Location of groundwater quality monitoring sites in the Wellington Region. Automated saline intrusion (conductivity) groundwater monitoring sites are also shown (red stars)

2.3 Monitoring variables

The GQSoE network is sampled quarterly for a wide range of physio-chemical and microbiological variables. Groundwater samples are collected by trained GWRC staff using nationally accepted protocols (Ministry for the Environment 2006).

Groundwater quality is assessed by measuring 31 different variables including pH, conductivity, turbidity, faecal indicator bacteria, total organic carbon, dissolved nutrients and major ions. A full list of the variables measured and the analytical methods used are provided in Appendix B.

For this report, only trends in nitrate-nitrogen are assessed. Nitrate-nitrogen was chosen for assessment because of its solubility, mobility, and potential to affect surface water bodies.

3. Trend Analysis Methodology

The following section outlines the methodology used to assess trends in the nitrate-nitrogen data. Data preparation did not include screening for charge balance error and all nitrate-nitrogen samples for the analytical period were used.

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 total of 25 sites from the nitrate-nitrogen trend analysis, leaving 46 sites.

Individual outliers were removed from each site's dataset at a total of seven sites (R25/5164, R25/5165, R25/5233, R25/6503, S26/0846, S27/0156, S27/0396). Outliers were identified as being three standard deviations from the mean.

All trend analysis was conducted by first examining each variable for seasonality (i.e., two seasons) using a Mann-Whitney U 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). A total of 17 sites were analysed using the two Two-Season Seasonal Kendall test. Trend analysis was undertaken using Time Trends (NIWA, 2011).

Where no seasonality was evident, trend analysis was performed using the Mann Kendall test. A total of 29 sites were analysed using the Mann-Kendall methodology.

4. Results

4.1 Trend analysis

Following the data preparation described in Section 3.2 above, a total of 46 sites were assessed for trends in nitrate nitrogen. A summary of the trends is presented in Table 4.1 below.

For interpretation of trends, the following criteria were used:

- A trend is significant if the *p*-value of the Mann-Kendal or Seasonal Kendal 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 nitrate. There are no guidelines as to acceptable rates of change in groundwater quality but an arbitrary threshold of 5% has been adopted by GWRC previously (Tidswell et al., 2012), with rates of change above this magnitude considered due to anthropogenic influence and therefore environmentally meaningful.
- 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).
- Sites that meet the requirements of the two criteria listed above are referred to as having a ‘meaningful trend’ in Table 4.1. These sites are a subset of sites identified as having a ‘significant trend’.

Meaningful trends were found in 14 wells (see Table 4.2).

Table 4.1: Summary of nitrate nitrogen trends (2003 – 2016)

Variable	Deteriorating Trends		No trend	Improving trend		Censored sites
	Sig. increase	Meaningful increase		Sig. decrease	Meaningful decrease	
Nitrate-N	6	3	21	19	11	25

Table 4.2: Summary of environmentally meaningful (i.e. statistically significant and a relative rate of change >5%/year, or absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr) temporal trends in nitrate measured quarterly in 69 GQSoE bores between 1 July 2003 and 31 June 2016 using the Mann-Kendall test and Sen's slope estimator. Bolded median values exceed ANZECC (2000) aquatic toxicity guidelines (2.4 mg/L).

Site	***n***	**Median value**	***p*-value**	**Median annual Sen slope**	**Relative rate of change (%/yr)**	**Test**
Increasing Trend						
R27/1137	53	1.07	0.017	0.072	6.73	MK
S27/0156	46	0.005	0.001	0.001	20.00	SK
S27/0299	48	0.3	0	0.015	5.00	MK
Decreasing Trend						
R25/5190	51	**5**	0	-0.289	-5.78	MK
R27/1265	47	0.172	0	-0.015	-8.72	MK
S25/5256	32	**9.5**	0	-0.281	-2.96	MK
S26/0824	52	**5.15**	0	-0.123	-2.39	MK
S27/0136	50	**4.28**	0	-0.397	-9.28	MK
S27/0202	51	**2.85**	0	-0.173	-6.07	MK
S27/0571	47	**8.1**	0	-0.371	-4.58	MK
T26/0099	51	**4.4**	0	-0.425	-9.66	MK
T26/0430	51	1.565	0.023	-0.089	-5.69	MK
T26/0538	50	**10**	0	-0.3	-3.00	MK
T27/0063	44	1.355	0	-0.183	-13.51	MK

Meaningful increases in nitrate-N were observed in R27/1137 (Upper Hutt), S27/0156 (Wairarapa) and S27/0299 (Wairarapa). These three wells all exhibited rates of change >5%. In all three cases however, the relative rate of change was less than 0.1 mg/L and the median concentrations are all significantly below the ANZECC toxicity guideline (2.4 mg/L). Plots of the concentration over time in these three wells are presented in Figure 4.1 below.

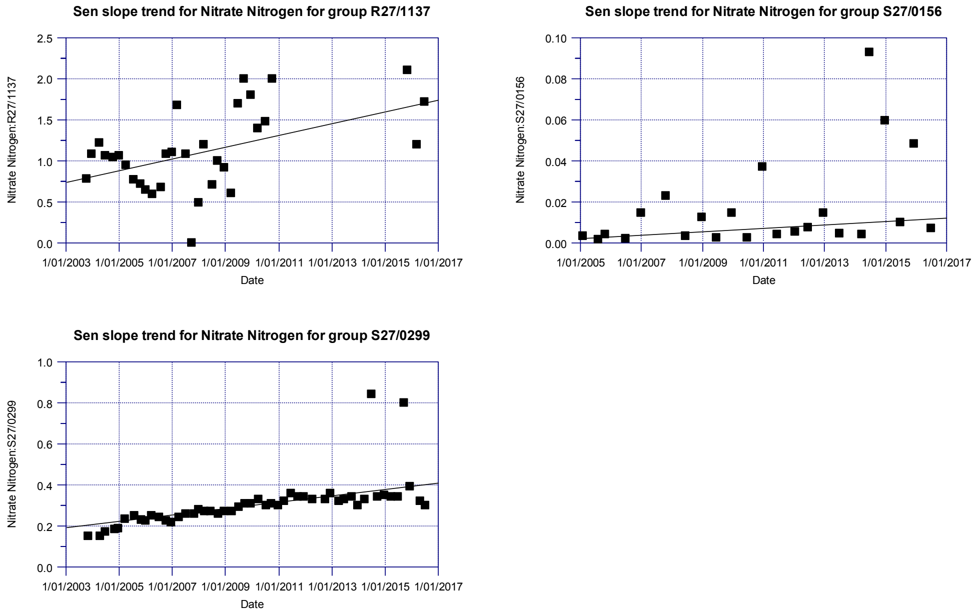
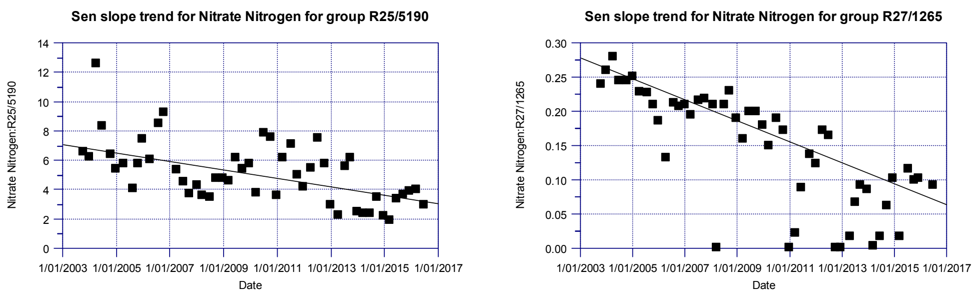


Figure 4.1: Increasing nitrate nitrogen concentrations recorded in three GQSoE wells sampled over from 2003 to 2016. The black line indicates the Mann Kendall slope trend line.

Meaningful decreases in nitrate concentrations were found in 11 wells (including seven in the Wairarapa Valley, one in Riversdale, two in Kapiti and one in the Hutt Valley). Seven of these wells (R25/5190, R27/1265, S27/0136, S27/0202, T26/0299, T26/0430 and T27/0063) exhibited decreasing trends in nitrate concentrations of a magnitude greater than 5% (5.7%, 8.7%, 9.2%, 6.0%, 9.6%, 5.6% and 13% respectively).

The remaining four wells (S25/5256, S26/0824, S27/0571 and T26/0538) recorded decreasing trends in nitrate concentrations at an absolute rate exceeding 0.1 mg/L/yr (-0.28, -0.12, -0.37 and -0.3 mg/L/yr respectively). Plots of the concentration over time in these three wells are presented in Figure 4.2 below.

With the exception of R27/1265, T26/0430 and T26/0063 all of the wells with decreasing trends had median nitrate concentrations greater than the ANZECC toxicity guideline (2.4 mg/L).



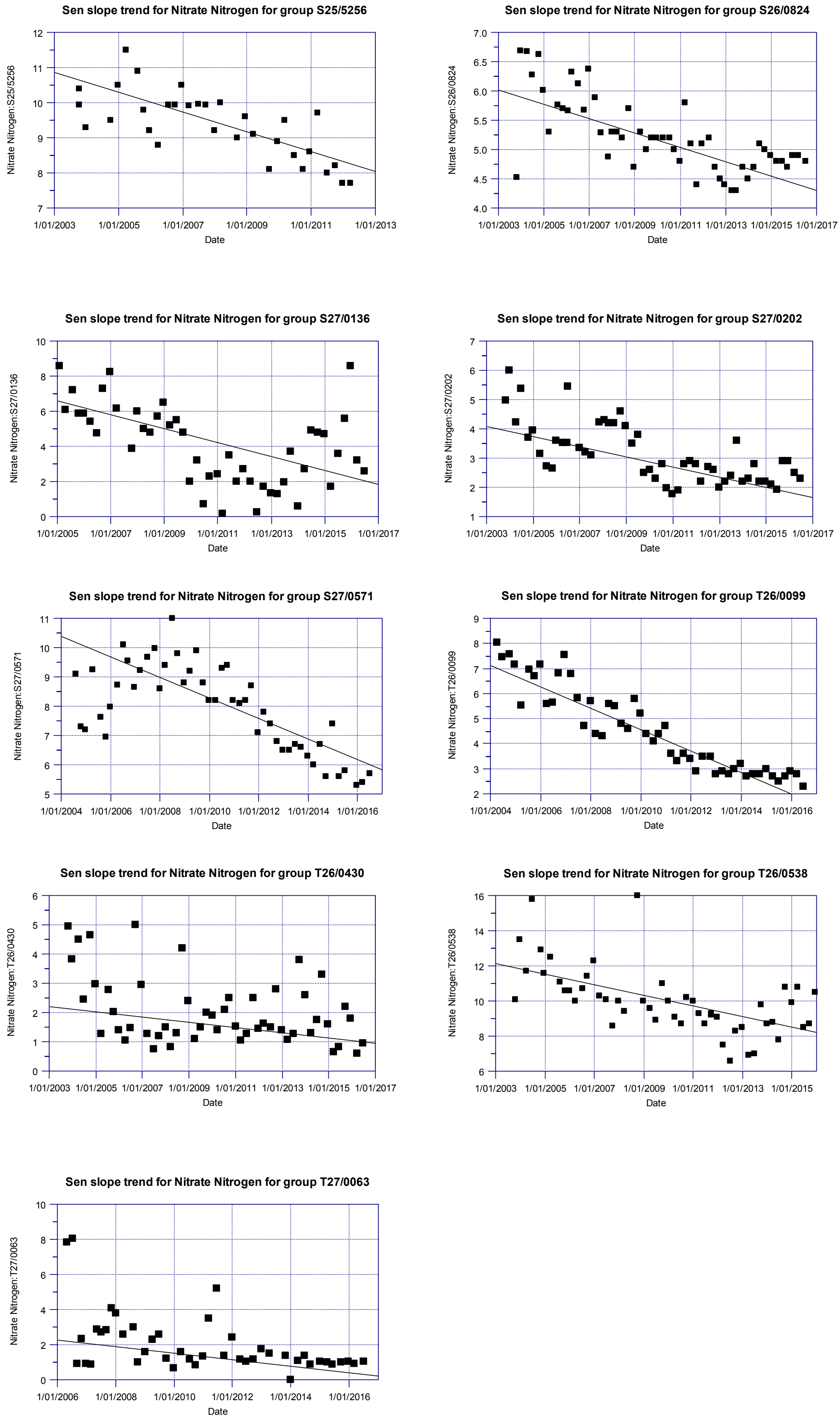


Figure 4.2: Decreasing nitrate nitrogen concentrations recorded in seven GQSoE wells sampled over from 2003 to 2016

Decreasing concentrations of nitrate in all instances are most likely due to a reduction of nitrate contamination in the recharge areas but this assumption requires further investigation.

(a) Environmental significance

While all of the 14 trends listed in Table 4.2 are considered environmentally meaningful (i.e. statistically significant and a rate of change of >5% per year), based on the median values recorded over the five-year reporting period, none of the nitrate-N levels pose a concern from a drinking water perspective.

It is important not to overstate the absence of many statistically significant and environmentally meaningful trends in the GQSoE monitoring results. While almost 46% of the 46 trend test results able to be generated fell into this category, the absence of environmentally meaningful trends should 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 is present at elevated concentrations in over 18% of the 69 GQSoE bores.

5. Source of the nitrate - capture zones

Having an understanding of the sources of nitrate and area of land contributing to the individual well used as a sampling site for the GWQ network is important to enable consideration of future land management and policy actions. For the purposes of this report, the delineated capture zone for each well is considered to be the likely source area for nitrogen.

In 2015 GWRC commissioned GNS to delineate capture zones (CZ) for community supply wells and for State of the Environment (SOE) wells (Toews & Donath, 2015). Capture zones are defined by GNS as being the total source area that contributes groundwater to a well.

Only wells that were located within the model domain of Greater Wellington's existing groundwater flow models (Hutt Valley, Kapiti Coast and Wairarapa) had CZs delineated. Of the 14 wells identified as having significant trends, only R27/1137 in Upper Hutt and T27/0063 located in Riversdale Beach have not had capture zones delineated.

The capture zones delineated by GNS and used in this reported are presented in Table and in Appendix C (Figures C1- C8).

Table 5.1: Capture Zone descriptions for sites with environmentally meaningful (i.e. statistically significant and a relative rate of change >5%/year, or absolute rate of change for nitrate nitrogen of >0.1 mg/L/yr) temporal trends in nitrate

Site	*Whaitua*	Groundwater Zone	Capture Zone Area (ha)
Increasing trend			
R27/1137	Hutt Valley	Upper Hutt	Not delineated
S27/0156	Ruamahanga	Tauherenikau	326
S27/0299	Ruamahanga	Lake Basin	933
Decreasing trend			
R25/5190	Kapiti	Coastal	3
R27/1265	Hutt Valley	Lower Hutt	353
S25/5256	Kapiti	Hautere	42
S26/0824	Ruamahanga	Mangatarere	1896
S27/0136	Ruamahanga	Tauherenikau	180
S27/0202	Ruamahanga	Tauherenikau	306
S27/0571	Ruamahanga	Martinborough Terraces	1416
T26/0099	Ruamahanga	Waipoua	194
T26/0430	Ruamahanga	Waingawa	172
T26/0538	Ruamahanga	Te Ore Ore	750
T27/0063	Wairarapa Coast	Riversdale	Not delineated

Using the CZ described above, an analysis of land use, and land use change over time has been undertaken. This is presented in the following section.

6. Land use Analysis

Land use practices can influence groundwater quality especially in shallow and unconfined aquifers where there is a greater hydraulic connectivity between the surface and unconfined aquifers. In the case of nitrate-nitrogen, background concentrations (non-anthropogenic) are low - typically less than 1 mg/L (Daughney and Reeves, 2005; Morgenstern and Daughney, 2012) and therefore elevated concentrations are generally considered a reflection of land use (anthropogenic sources).

To determine the current and historical land use within each CZ, the national spatial farms agricultural database 'Agribase' was used. Agribase is owned by AsureQuality and holds key contact details for the farm, type, size, animal numbers by stock class and planted areas for different orchard or crop types. The most recent Agribase layer held by GWRC is 2012. For historical comparison the 2001 layer was also used.

The full list of land use categories is listed below:

- Arable
- Beef
- Dairy
- Deer
- Drystock
- Forest
- Fruit growing
- Goat
- Grazing
- Horticulture
- Lifestyle
- Native bush
- New record
- Not farmed
- Plant nurseries
- Other planted types
- Ostrich
- Other
- Poultry
- Sheep
- Sheep and beef
- Tourism
- Unspecified[1]
- Vegetable
- Viticulture
- Blank[2] (not in database)

[1] Unspecified is where a land owner has not specified what land use type it is
[2] Blank is land within the delineated groundwater capture zone that is not included in the Agribase coverage. This is typically river bed and Queen's Chain land.

Land use data from the Agribase Layers is presented in Appendix D (Tables D1 – D5), and is summarised below in Table 6.1.

Table 6.1: Summary of Land use change 2001 – 2012

Site	Groundwater Zone	Depth (m BGL)	Capture Zone Area (ha)	Significant land use change summary
Increasing trend				
R27/1137	Upper Hutt	20.4	Not calculated	Based on aerial photograph reviews, the general area is dominated by residential and light commercial/industrial. No significant land use change between 2001 and 2012
S27/0156	Tauherenikau	20.7	326	Increase in lifestyle block ~ 34 ha Increase in dairy & grazing ~15 ha Decrease in sheep and beef ~50 ha
S27/0299	Lake Basin	17.4	933	Decrease of Sheep & Beef ~40 ha Increase in Dairy ~36 ha Increase in lifestyle ~ 5 ha Increase in horticulture ~ 5 ha
Decreasing trend				
R25/5190	Coastal	5.0	3	No significant change
R27/1265	Lower Hutt	48.3	353	No significant change – predominantly urban
S25/5256	Hautere	30.8	42	Decrease in beef and other farming activities ~8 ha Increase in lifestyle ~ 8 ha
S26/0824	Mangatarere	20.6	1896	Decrease in arable ~ 114 ha Decrease in sheep, beef and other farming ~110 ha Decrease in non-specified land ~ 100 ha Increase in lifestyle ~ 200 ha Increase in grazing ~ 116 ha
S27/0136	Tauherenikau	20.4	180	Decrease in unclassified ~28 ha Increase in dairy ~ 30 ha
S27/0202	Tauherenikau	4.8	306	Decrease in unclassified ~ 52 ha Increase in Dairy ~ 60 ha
S27/0571	Martinborough Terraces	32	1416	Decrease in Drystock ~ 204 ha Decrease in Dairy ~ 10 ha Decrease in Unclassified ~ 80 ha Increase in Other Land use ~ 40 ha Increase in Viticulture ~ 175 ha Increase in lifestyle ~ 65 ha

Site	Groundwater Zone	Depth (m BGL)	Capture Zone Area (ha)	Significant land use change summary
T26/0099	Waipoua	15	194	Decrease in Grazing, Beef & Fruit ~ 50 ha Increase in Lifestyle ~ 15 ha Increase in Viticulture ~ 42 ha
T26/0430	Waingawa	Spring	172	Decrease in sheep & beef ~ 11 ha Decrease in Unspecifed and Blank ~23 ha Increase in Lifestyle ~22 ha Increase in tourism ~ 4ha Increase in Deer ~ 6 ha
T26/0538	Te Ore Ore	9	750	Decrease in sheep and beef ~ 40 ha Decrease in unspecified/Blank ~ 35 ha Increase in Dairy ~ 30 ha Increase in Lifestyle ~ 24 ha Increase in deer, new record and viticulture ~ 20 ha
T27/0063	Riversdale	3.6	Not calculated	Predominantly Urban and Lifestyle – no significant change

7. Discussion

Increasing trends were observed in three wells (Upper Hutt, Tauherenikau and Lake Basin) and decreasing trends were observed in 11 wells, including seven in the Wairarapa Valley, two in Kapiti and two in the Hutt Valley.

It is important to note that all three of the wells with increasing trends have low median concentrations that range from 0.005 to 1.07 mg/L. These concentrations are not considered environmentally significant as they are below the 2.4 mg/L ANZEC threshold.

Each of the wells identified as having a meaningful trend are discussed in further detail below and considered in respect to land use change and capture zone extent.

7.1 Increasing Trend Sites

R27/1137 (Upper Hutt)

This well is the former South Pacific Tyres industrial supply well that has been taken over by Wellington Water for use as an emergency public supply well. It is located in an urban area, with no surrounding agricultural land use. The well was previously used on a daily basis for processes within the factory; however it now sits idle and is only operated on a sporadic basis.

The groundwater catchment has not been modelled, but is likely to extend north and east across to the Eastern Hutt foothills. Potential sources of nitrate-N in this area include playing fields, industrial and/or commercial activities, and compromised infrastructure (wastewater and storm water).

At this stage the source of the increasing nitrate is not clear and further investigation is required. Further investigation could consider the influence of decreased pumping of the local aquifer on water quality.

S27/0156 (Tauherenikau)

The well is a farm supply well and is located in the Tauherenikau groundwater management zone.

While this site has a meaningful trend ($p < 0.05$) and a 20% annual rate of change, the mean concentration at this site is very low (0.005 mg/L), and not of environmental significance.

Land use in the groundwater capture zone is dominated by sheep and beef farming but has seen increases in dairy and lifestyle blocks over the analysis period. Groundwater at this site is marginally anoxic (GNS, 2010) and is likely to have a moderate potential for denitrification. Denitrification is a microbially driven process where nitrate is reduced and ultimately transformed into nitrogen (gas).

Increasing nitrate (albeit at low concentrations), may be a reflection of the increased dairy land use in this catchment, however this would require further investigation to confirm.

S27/0299 (Lake Basin)

This well is 17 m deep and is located adjacent to the Tauherenikau River. The capture zone broadly follows the river and as a result, groundwater at this location is likely to be influenced by losses from the river.

Again, while this site has a meaningful trend ($p < 0.05$) and a 5% annual rate of change, the mean concentration at this site is very low (0.03 mg/L), and not considered to be of environmental significance.

Land use in the catchment is dominated by sheep and beef Farming (55%), and dairy farming (20%), the latter of which has increased by 40 ha over the analysis period. The increase in nitrate nitrogen may be a reflection of the increased dairying in the catchment, however given the concentrations it is not considered to be of environmental concern at present.

7.2 Decreasing Trend Sites

R25/5190 (Coastal)

This well is located in sand hill country just up-gradient of the Te Hapua wetland complex. The well has a very small capture zone, and as a result is largely reflective of land use in the immediate vicinity (100 m radius) of the well. Land use comprises mainly open pasture as part of a lifestyle block. No changes in land use have been observed.

The site has an environmentally meaningful decrease in nitrate concentrations over the sampling record; it has decreased from close to the drinking water standard (~10 mg/L) down to 4 mg/L. The reason for the decreasing trend is unclear, however given the small capture zone, it is not considered reflective of wider aquifer conditions.

R27/1265 (Lower Hutt)

This well (known as IBM 2 and an ex Gear Meatworks supply well) is screened in the Waiwhetu aquifer in the Lower Hutt Valley. The Waiwhetu aquifer is predominantly sourced form losses in the Hutt River so the source zone captures both the urban land use in the Hutt and the wider Hutt catchment.

Median nitrate concentrations at this site are low (0.17 mg/L) and not environmentally significant, however they have decreased from around 0.3 mg/L to < 0.1 mg/L over the period analysed. Land use over this time has not changed significantly so the reason for the decreasing trend is not clear, however further investigation into the influence of Hutt River water quality should be undertaken.

S25/5256 (Hautere)

This well is located on the Hautere plains, between Otaki and Te Horo. Nitrate concentrations have decreased significantly at this location from ~15 mg/L in the early 1990s, to less than 8 mg/L in 2016. Prior to 1990 there was a lot of horticultural land use across the plains, however through the late 1980s and 1990s much of this was converted to lifestyle and dairy. The decrease in nitrate concentrations is likely to be reflective of this de-intensification of land use that occurred during this time.

S27/0136 (Tauherenikau)

This site is located on the Tauherenikau Plains upgradient of S27/0156 (discussed above).

The site has a meaningful trend ($p < 0.05$) and a -9.3 % annual rate of change. The mean concertation is 4.3 mg/L and has been decreasing at a rate of 0.4 mg/L per year.

The groundwater catchment of the bore is dominated by sheep and beef farming (60%) and dairy (30%). According to Agribase, the land coverage of dairying has increased by 30ha over the data period, however this is the same area as was unclassified in 2001.

Groundwater has a mean residence time of approximately 40 years at this site, so it is likely that the changes observed are a reflection of long term changes in land use practice or historic land use changes.

S27/0202 (Tauherenikau)

This site is also located on the Tauherenikau Plains upgradient of S27/0156 (discussed above).

The site has a meaningful trend ($p < 0.05$) and a -6 % annual rate of change. The mean concentration at this site is 2.8 mg/L.

The groundwater catchment is dominated by dairy and grazing (50%) and sheep and beef (42%). The change in land use over the analysis period was an increase in dairying, although it is likely that this was the 'blank' land use in 2001.

Groundwater has a mean residence time of approximately 40 years at this site, so it is likely that the changes observed are a reflection of long term changes in land use practice or historic land use changes.

T26/0099 (Waipoua)

This site is located in the Waipoua groundwater zone, north of Masterton. The capture zone of this well is dominated by sheep and beef farming (63%), viticulture (21%) and lifestyle (9%). Almost all of the land area currently covered by viticulture and lifestyle has converted from sheep and beef since 2001.

The decrease in sheep and beef farming appears to be the main reason for the observed decreases in nitrate-N at this well. Even though sheep and beef farming have lower nitrogen inputs than dairying, the results at this site suggest that sheep and beef farming can have an influence on groundwater quality.

T26/0430 (Waingawa)

This site is the Trout Hatchery Spring, located at the base of the Masterton Fault line in Solway, Masterton. The capture zone for this well is long and narrow and extends across the Upper Plain toward the Waingawa River.

While this site has a meaningful trend ($p < 0.05$) and a -5.7 %/yr rate of change, the mean concentration at this site is very low (1.56 mg/L) and not of environmental significance.

The land use of the capture zone is predominantly deer farming (23%), lifestyle (18%) and sheep and beef (15%). Between 2001 and 2012 the main land use change was an increase in lifestyle by 20 ha, replacing sheep and beef farming.

The mean residence time at this spring is 1.5 years, which is very young. Whilst the water is reflective of very recent land drainage, the trend in the historical data set is very consistent. This may be a reflection of the gradual increase in lifestyle replacing agricultural land uses in the catchment.

T27/0063 (Riversdale)

This is a shallow groundwater monitoring site located at Riversdale beach. The capture zone for this site is small (up to 150 m radius) and land use within it is entirely residential.

This site has a meaningful trend ($p < 0.05$) and a -13 % annual rate of change. The median concentration is 1.5 mg/L and is considered significant because the absolute rate of change is -0.18 mg/L/yr.

This well was installed to monitor the effects of onsite wastewater discharges when all of Riversdale was reliant on septic tank systems. In 2010/11 Masterton District Council constructed a reticulated sewage scheme for Riversdale and all households were connected to it. As a result of this, groundwater nitrate concentrations have started to decrease, and are consistently below 2 mg/L, down from above 8 mg/L in 2006.

S26/0824 (Mangatarere)

This site is the shallowest of the Carterton District Council water supply wells. It has a large capture zone that extends northwards beneath the Mangatarere Stream and is likely to also receive recharge from the Waiohine River. Mean residence time at this well has been estimated by GNS as being in the order of 40 years.

This site has a meaningful trend ($p < 0.05$) and a -2.3 % annual rate of change. The mean concentration at this site is 5.15 mg/L and is considered significant because the absolute rate of change is -0.12 mg/L/yr.

Land use in the capture zone is predominantly dairying (41%), sheep and beef (21%) and lifestyle (11%). Between 2001 and 2012 arable, sheep and beef decreased by 225 ha, lifestyle increased by 200 ha and grazing increased by 116 ha. It is likely the decreasing nitrate concentrations are a reflection of lifestyle properties replacing land that was previously agricultural (sheep, beef or dairy land.

S27/0571 (Martinborough)

This bore is located at the Martinborough Golf Club, on the Martinborough Terraces. It has a large capture zone that extends across the terraces, and up the Huangarua River. Mean residence time has been estimated by GNS as being in the order of 60 years.

This site has a meaningful trend ($p < 0.05$) and a -4.4% annual rate of change. The mean concentration at this site is 8.15 mg/L considered significant because the absolute rate of change is -0.4 mg/L/yr.

Land use in the capture zone is predominantly sheep and beef farming (50%) and viticulture (12%). Between 2001 and 2012 the main change in land use was an increase of viticulture (175 ha) and lifestyle (65 ha). This corresponded to an almost equal decrease in sheep and beef farming. It is likely the decreasing nitrate concentrations are a reflection of viticulture and lifestyle properties replacing land that was previously agricultural (sheep, beef or dairy land.

T26/0538 (Te Ore Ore)

This location is a shallow (9 m) well located in the Te Ore Ore groundwater zone, east of Masterton. The capture zone extends in a Y shape up to the Ruamahanga and across to the Whangaehu River. The mean residence time of groundwater from this well has been estimated by GNS to be in the order of 20 years.

This site has a meaningful trend ($p < 0.05$) and a -3% per year rate of change. The mean concentration at this site is 10 mg/L and the site is considered significant because the absolute rate of change is -0.3 mg/L/yr.

Land use in the zone is predominantly sheep and beef (46%) and dairy (30%). Between 2001 and 2012 the main change in land use was a decrease in sheep and beef of 40 ha, and increases in dairy (~30 ha) and lifestyle (~24 ha).

The Te Ore Ore groundwater zone has had a long history of elevated nitrate nitrogen concentrations. A detailed study of the aquifer by van der Raaij (2000) concluded that the source of nitrate was most likely a fertiliser or natural soil nitrate source (such as clover fixation). The age dating presented in this study indicates that the source of nitrate was a land use that had been practiced on the plains for at least 20 years.

8. Conclusions and recommendations

Overall, several common themes were observed in the trend data:

- Increased pastoral based farming (dairy, sheep and beef) appears to result in increased groundwater nitrate-nitrogen concentrations
- The conversion of pastoral farming operations (dairy, sheep and beef) to lifestyle and/or viticulture results in a decrease in nitrate-nitrogen concentrations in groundwater
- In a single case, the replacement of septic tanks with a reticulated wastewater scheme appears to be leading to improvements in groundwater quality
- Groundwater reacts differently to land use (or drainage) depending on a number of factors including soil type, depth of vadose zone, recharge volume, mean residence time, aquifer geochemistry and aquifer hydraulic properties. As such, the same land use change across two different capture zones may not necessarily result in the same response.
- Determining the cause of a trend in groundwater is complex, as there are multiple factors influencing the cause

The analyses have highlighted that the occurrence and distribution of trends is complex and not all monitoring sites are directly comparable to each other. Overall, the fact that only three sites out of 46 analysed had a meaningful deteriorating trend (increase in nitrate-nitrogen) is a positive outcome, as is the number of meaningful decreasing trends (11) that were observed.

This trend analysis process has raised a number of questions about the representativeness of the current groundwater quality monitoring network. Some of the questions raised are:

- The majority of meaningful trends (decreasing) observed are primarily in zones dominated by sheep and beef farming. Does this mean that dairy farming is not resulting in trends (either decreasing or increasing) or is it that the network is biased toward sheep and beef?
- The current monitoring network is made up of both shallow and deep wells. Many of the deeper wells are in aquifers unlikely to be affected by land use change because of their geochemistry (reduced and denitrifying conditions). Given this, how representative are the remaining shallow wells of the relative distribution of land uses, and nitrate influencing factors across the region?
- Is just measuring nitrate-nitrogen enough, or should nitrogen isotope analyses be included in the suite of analyses so that the source of nitrate can be tracked over time?

- Should the monitoring wells in the network be representative of land use types, areas of environmental sensitivity (i.e. where groundwater may influence surface water quality), areas of groundwater use, or all of the above?

These questions are best addressed as part of a review of the GQSoE network. An outcome of this review should be that GWRC are confident that the GQSoE is fairly representative of the range of land uses and hydrogeological conditions across the region. It is also recommended that the trends identified in this report are compared to trend analyses currently being undertaken on surface water data.

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Appendix A: Groundwater quality SoE monitoring sites

Table A1: List of groundwater quality SOE monitoring sites

Site number	Site name	X coordinates	Y coordinates	Groundwater zone	Category
Kapiti Coast					
R25/5100	O'Malley	1774552.15	5479451.35	Te Horo	Category B
R25/5135	Windsor Park	1779152.45	5481483.39	Te Horo	Category C
R25/5164	Card	1775873.28	5482367.50	Te Horo	Category B
R25/5165	Salter	1776019.28	5481886.47	Te Horo	Category B
R25/5190	Williams	1776678.23	5478988.27	Te Horo	Category B
R25/5233	Otaki Porirua Trust	1779397.56	5487564.84	Otaki	Category A
R26/6503	Queen Elizabeth Park	1766253.09	5462295.15	Raumati	Category B
R26/6587	Liddle	1772633.83	5473057.09	Waikanae	Category A
R26/6624	Boffa	1773932.93	5474297.10	Waikanae	Category B
S25/5125	Betty Partnership	1782733.73	5483013.44	Otaki	Category A
S25/5200	Common Property	1781182.52	5479785.21	Te Horo	Category C
S25/5256	Penray	1780490.58	5483153.49	Te Horo	Category C
S25/5322	Edhouse	1782982.85	5487485.83	Otaki	Category C
Hutt, Mangaroa and Wainuiomata Valley					
R27/0320	IBM 1	1756996.50	5434507.51	Hutt Valley	Category B
R27/1137	South Pacific Tyres	1773406.32	5444956.34	Hutt Valley	Category A
R27/1171	Somes Island	1756493.07	5431226.71	Hutt Valley	Category B
R27/1180	Mahoe/Willoughby St	1760435.48	5435698.05	Hutt Valley	Category B
R27/1182	Seaview Wools	1759274.04	5432161.32	Hutt Valley	Category B
R27/1183	Television New Zealand	1763083.77	5438690.64	Hutt Valley	Category A
R27/1265	IBM 2	1756997.50	5434515.51	Hutt Valley	Category B
R27/6418	Wainuiomata Golf Club	1762217.86	5425695.18	Wainuiomata	Unknown
R27/6833	Mangaroa School	1777716.35	5445323.81	Mangaroa	Unknown
Wairarapa Valley					
S26/0117	Butcher, G	1811483.15	5456780.11	Mangatarere	Category A
S26/0223	Nicholson	1816203.19	5459284.79	Taratahi	Category B
S26/0299	Graham	1818354.91	5461869.91	Taratahi	Category B
S26/0439	Rogers	1807492.42	5455180.48	Mangatarere	Category B
S26/0457	Palmer Berry Fruits	1807656.62	5450330.89	Waiohine	Category A
S26/0467	Fitzgerald	1809272.40	5453850.06	Mangatarere	Category A
S26/0568	Denbee	1813486.57	5451921.15	Parkvale	Category B
S26/0576	Mcnamara	1813461.67	5452534.23	Parkvale	Category B
S26/0705	Carterton District Council South	1810471.61	5454278.93	Mangatarere	Category B
S26/0756	Stevenson	1815919.19	5448296.24	Middle Ruamahanga	Category A
S26/0762	Schaef	1815702.37	5449348.42	Middle Ruamahanga	Category A
S26/0824	Carterton District Council North	1810546.63	5454380.93	Mangatarere	Category B
S26/0846	Druzianic	1807902.50	5449491.76	Waiohine	Category A
S27/0009	Dondertman	1793895.42	5443481.45	Tauherenikau	Category B
S27/0070	South Featherston School	1797507.54	5443110.86	Tauherenikau	Category B
S27/0136	Sugrue	1802217.44	5446389.36	Tauherenikau	Category B
S27/0156	O'Neale	1803402.88	5442775.85	Tauherenikau	Category B
S27/0202	Croad	1805460.73	5446519.85	Tauherenikau	Category B
S27/0268	Barton	1793452.70	5434055.07	Lake	Category B
S27/0283	Osborne	1797276.24	5436168.48	Tauherenikau	Category B
S27/0299	Johnson	1796503.73	5438935.77	Tauherenikau	Category A
S27/0344	George	1803347.81	5437340.43	Lower Ruamahanga	Category A
S27/0389	Dimattina	1807205.35	5433792.40	Martinborough	Category C
S27/0396	SWDC Martinborough	1805858.70	5435961.84	Lower Ruamahanga	Category A
S27/0433	Mapuna Atea	1787692.45	5427838.97	Lake	Category B
S27/0435	Wairio	1787608.01	5430805.03	Lake	Category B
S27/0442	Robinson Transport	1789891.27	5426883.54	Lake	Category B
S27/0495	Bosch	1797227.31	5431330.26	Lower Ruamahanga	Category A
S27/0522	Duggan	1803031.58	5431324.10	Martinborough	Category C
S27/0571	Martinborough Golf Club	1807158.18	5433014.36	Martinborough	Category C
S27/0585	McCreary	1780320.53	5422598.32	Onoke	Category C

Site number	Site name	X coordinates	Y coordinates	Groundwater zone	Category
S27/0588	SWDC Piriona	1784844.06	5420713.48	Onoke	Category A
S27/0594	Warren	1781350.93	5419721.16	Onoke	Category C
S27/0602	Weatherstone	1789625.95	5425301.57	Lake	Category B
S27/0607	Finlayson	1786288.91	5425037.20	Lake	Category B
S27/0614	Sorenson South	1786778.28	5421924.10	Unknown	Unknown
S27/0615	Sorenson North	1786805.33	5422158.09	Unknown	Unknown
S27/0681	Te Kairanga Wines	1808952.42	5433542.02	Huangarua	Category A
T26/0003	Lenton	1822559.22	5473236.52	Upper Ruamahanga	Category B
T26/0087	Biss	1820295.66	5464750.15	Waingawa	Category C
T26/0099	Butcher, M	1822518.46	5467619.40	Upper Ruamahanga	Category B
T26/0206	Thornton	1822581.50	5467829.43	Upper Ruamahanga	Category B
T26/0259	Opaki Water Supply Association	1825997.33	5469120.23	Upper Ruamahanga	Category A
T26/0332	Taratahi Agricultural Training Centre	1822230.80	5457401.54	Fernhill-Tiffen	Category C
T26/0413	Seymour	1824485.62	5459978.64	Waingawa	Category B
T26/0430	Trout Hatchery	1822130.71	5463027.57	Waingawa	Category B
T26/0489	Duffy	1827571.49	5461854.50	Te Ore Ore	Category B
T26/0538	Percy	1827738.41	5461169.34	Te Ore Ore	Category B
Riversdale					
T27/0063	Acacia Ave	1858025.04	5446630.37	Riversdale	Unknown
Saline intrusion monitoring					
R26/6956	Waikanae Estuary Deep	1769406.76	5473310.22	Waikanae	Category A
R27/0122	McEwan Park Shallow	1758681.27	5433523.34	Hutt Valley	Category B
R27/7153	McEwan Park Deep	1758681.27	5433523.34	Hutt Valley	Category B
R27/7154	Tamatoa Deep	1757019.47	5434294.51	Hutt Valley	Category B
R27/7215	Tamatoa Shallow	1757021.47	5434298.51	Hutt Valley	Category B

Appendix B: Monitoring variables and analytical methods

Groundwater samples are collected quarterly by trained GWRC 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. Field measurements (temperature, conductivity, pH and dissolved oxygen) are taken using field meters which are 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. RJ Hill Laboratories in Hamilton analysed the samples for the variables listed in Table B1.

The rationale for variables monitored is detailed in Table B1 and analytical methods are summarised in Table B2.

Table B1: Rationale for inclusion in GQSoE sampling regime

Test type	Variable	Rationale for inclusion
Bacteria	Faecal coliforms *E. coli*	Faecal coliforms *and E. coli* can indicate pollution due to faecal matter and the presence of potentially harmful pathogens in groundwater. Ministry for the Environment uses *E. coli* as an indicator of ground water 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 extent of rock/water interaction. Concentrations of major ions can also be indicative of groundwater contamination from industrial, agricultural and domestic sources.
Nutrients	Total 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 biota. Total ammoniacal nitrogen usually exists under oxygen-poor conditions and represents the reduced form of nitrogen. Therefore, can be used as an indicator of contamination in the absence of nitrate nitrogen. The ANZECC guidelines (2000) state trigger values for the direct toxicity to biota.

Table B1 cont.: Rationale for inclusion in GQSoE sampling regime

Chemical tests	Variable	Rationale for inclusion in sampling regime
Metals	Dissolved iron Dissolved manganese Dissolved lead Dissolved zinc	Trace metals are usually present in groundwater at low concentrations. Elevated concentrations of trace metals can suggest contamination of groundwater. Elevated concentrations of dissolved of lead and manganese can have an adverse effect on human health.
Trace elements	Bromide Fluoride Dissolved boron	Bromide naturally occurs in water but can suggest contamination from wastewater and agricultural run off. Elevated concentrations of dissolved of boron can have an adverse effect on human health and the DWSNZ (2005) MAV for fluoride is set to protect against potential dental fluorosis.
Other	pH	Water with a low pH can have a high plumbosolvency. Measured in the field to identify when the bore is purged and sample can be collected.
	Electrical conductivity	Electrical conductivity can provide a measure of total dissolved solids. Measured in the field to identify when the bore is purged and sample can be collected.
	Dissolved oxygen	Dissolved oxygen can indicate whether groundwater is under reduced or oxidised conditions. Measured in the field to identify when the bore is purged and sample can be collected.
	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.

NB: Groundwater samples are also tested for arsenic, chromium, cadmium, nickel and copper but on a not routine basis. Conductivity and pH are tested both in the field and by Hills Laboratory. Dissolved oxygen is only tested for in the field.

Table B2: Analytical methods

Variable	Method Used	Detection Limit
Temperature	Field meter – WTW350i and YSI Professional Plus Meters	0.01 ˚C
Dissolved oxygen	Field meter – WTW350i and YSI Professional Plus Meters	0.01 mg/L
Electrical conductivity	Field meter – WTW350i and YSI Professional Plus Meters	0.1 µS/cm
pH	Field meter – WTW350i and YSI Professional Plus Meters	0.01 units
pH (lab)	pH meter APHA 4500-H+ B 22st ed. 2012.	0.1 pH units
Total alkalinity	Titration to pH 4.5 (M-alkalinity), Radiometer autotitrator. APHA 2320 B (Modified for alk <20) 22st ed. 2012.	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-CO_2 D 22st ed. 2012.	1 mg/L at 25°C
Free carbon dioxide	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-CO_2 D 22st ed. 2012.	1.0 mg/L at 25°C
Total hardness	Calculation from calcium and magnesium. APHA 2340 B 22st ed. 2012.	1.0 mg/L $CaCO_3$
Electrical conductivity (lab)	Conductivity meter, 25°C APHA 2510 B 22st ed. 2012.	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) 22st ed. 2012.	10 mg/L
Dissolved boron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.005 mg/L
Dissolved calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.05 mg/L
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.02 mg/L
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.0001 mg/L
Dissolved magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.02 mg/L
Dissolved manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.0005 mg/L
Dissolved potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.05 mg/L
Dissolved sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.02 mg/L
Dissolved zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22st ed. 2012.	0.001 mg/L
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 22st ed. 2012.	0.05 mg/L
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 22st ed. 2012.	0.5 mg/L
Fluoride	Ion selective electrode APHA 4500-F- C 22st ed. 2012.	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) 22st ed. 2012.	0.01 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22st ed. 2012.	0.002 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.001 mg/L
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3 - I (modified) 22st ed. 2012.	0.002 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22st ed. 2012.	0.004 mg/L
Reactive silica	Filtered sample. Heteropoly blue colorimetry. Discrete Analyser. APHA 4500-SiO2 F (modified from flow injection analysis) 22st ed. 2012.	0.1 mg/L as SiO_2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22st ed. 2012.	0.5 mg/L
Total organic carbon (TOC)	Supercritical persulphate oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 C (modified) 22st ed. 2012.	0.05 mg/L
Total anions	Calculation: sum of anions as mEquiv/L [Includes Alk, Cl, NO_xN, F, DRP & SO_4]. APHA 1030 E 22nd ed. 2012.	0.07 mEquiv/L
Total cations	Calculation: sum of cations as mEquiv/L [Includes pH (H^+), Ca, Mg, Na, K, Fe, Mn, Zn & NH_4N]. APHA 1030 E 22nd ed. 2012.	0.06 mEquiv/L
% Difference in Ion Balance	Calculation from Sum of Anions and Cations. Please note: The result reported for the '% Difference in Ion Balance' is an absolute difference between the 'Sum of Anions' and 'Sum of Cations' based on the formula	0.1 %

Variable	Method Used	Detection Limit
	taken from APHA. This does not indicate whether the 'Sum of Anions' or the 'Sum of Cations' produced a higher value. APHA APHA 1030 E 22nd ed. 2012.	
Faecal coliforms	Membrane filtration, count on mFC agar. Incubated at 44.5°C for 22 hours, confirmation. Analysed at Hill laboratories – Microbiology: 1 Clow Place, Hamilton. Method 9222 D 22st ed. 2012.	1 cfu/100 mL
E. coli	Membrane filtration, count on mFC agar. Incubated at 44.5°C for 22 hours, MUG confirmation. Analysed at Hill laboratories – Microbiology: 1 Clow Place, Hamilton. Method 9222 G 22st ed. 2012.	1 cfu/100 mL

Appendix C: Capture zones

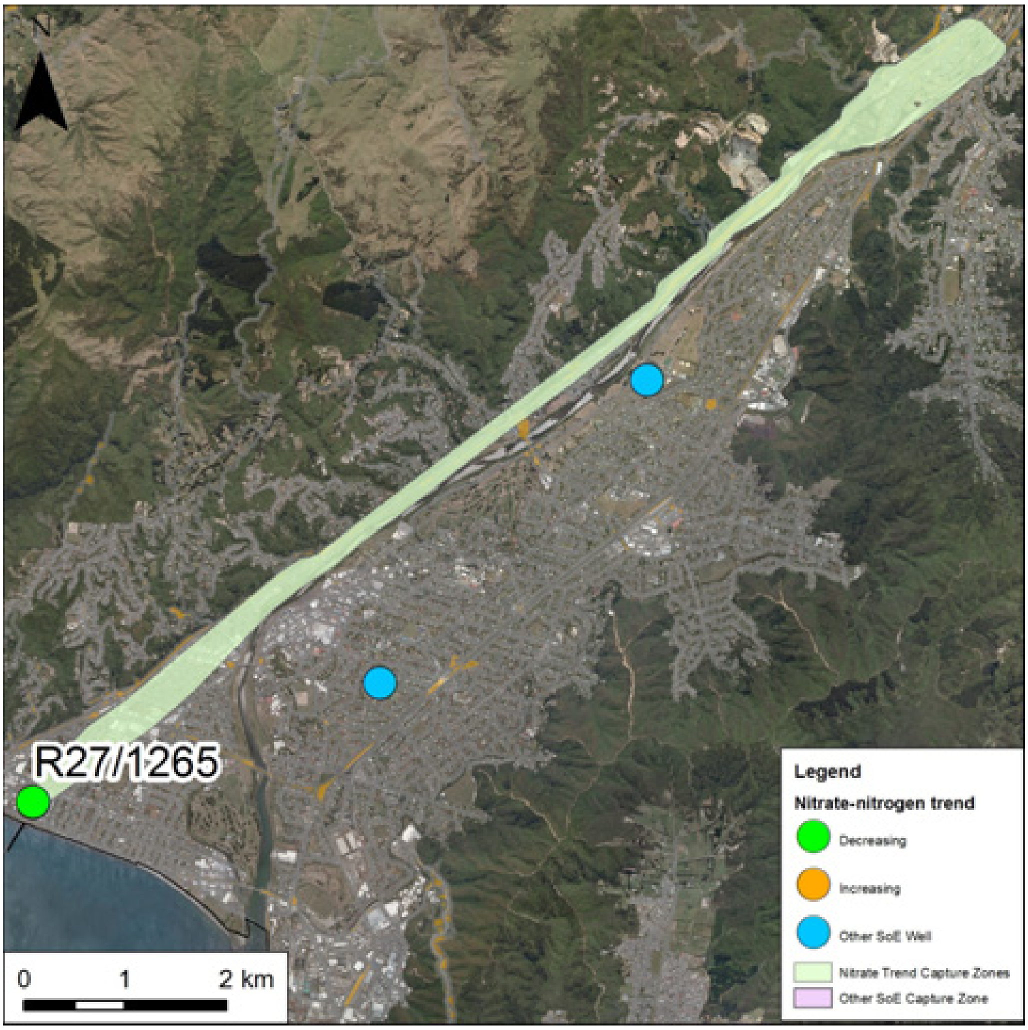

Figure C1: Lower Hutt Source Capture Zone

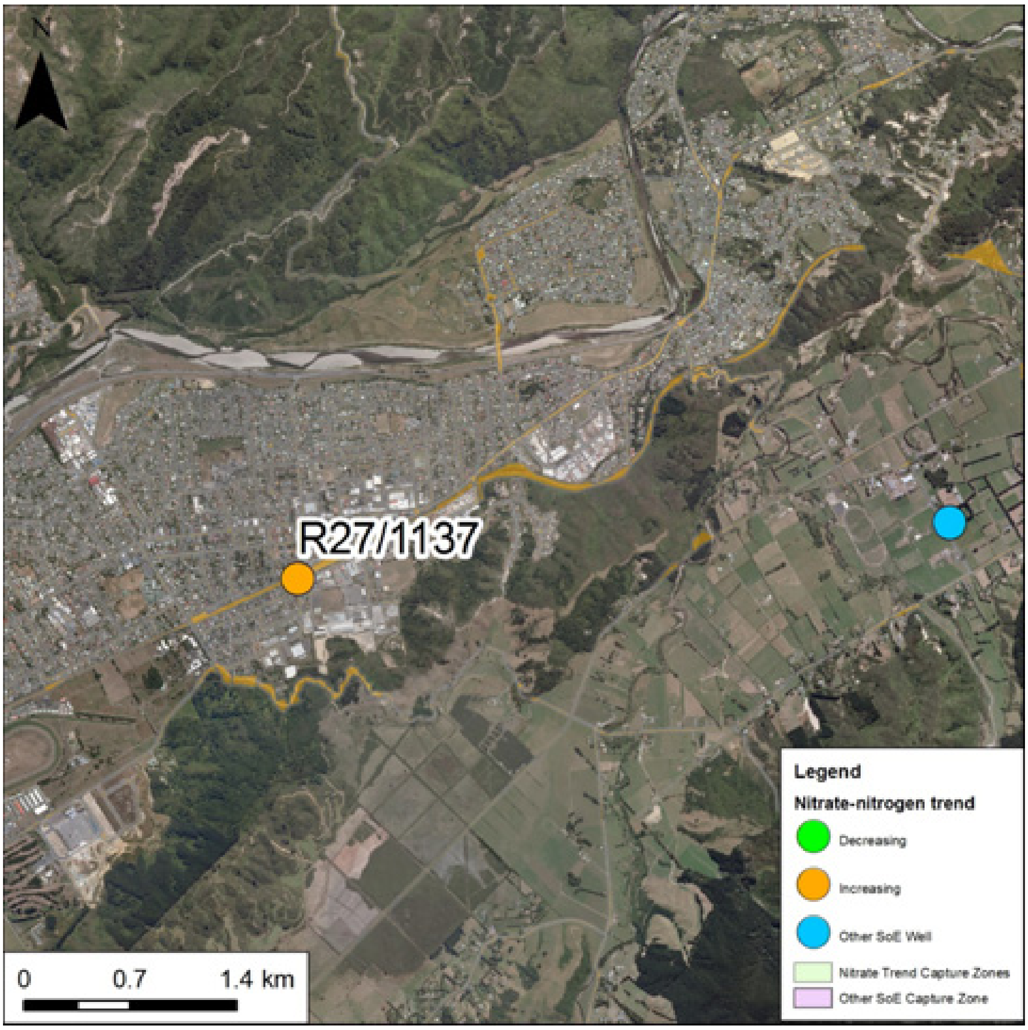

Figure C2: Upper Hutt Source Capture Zone (not delineated)

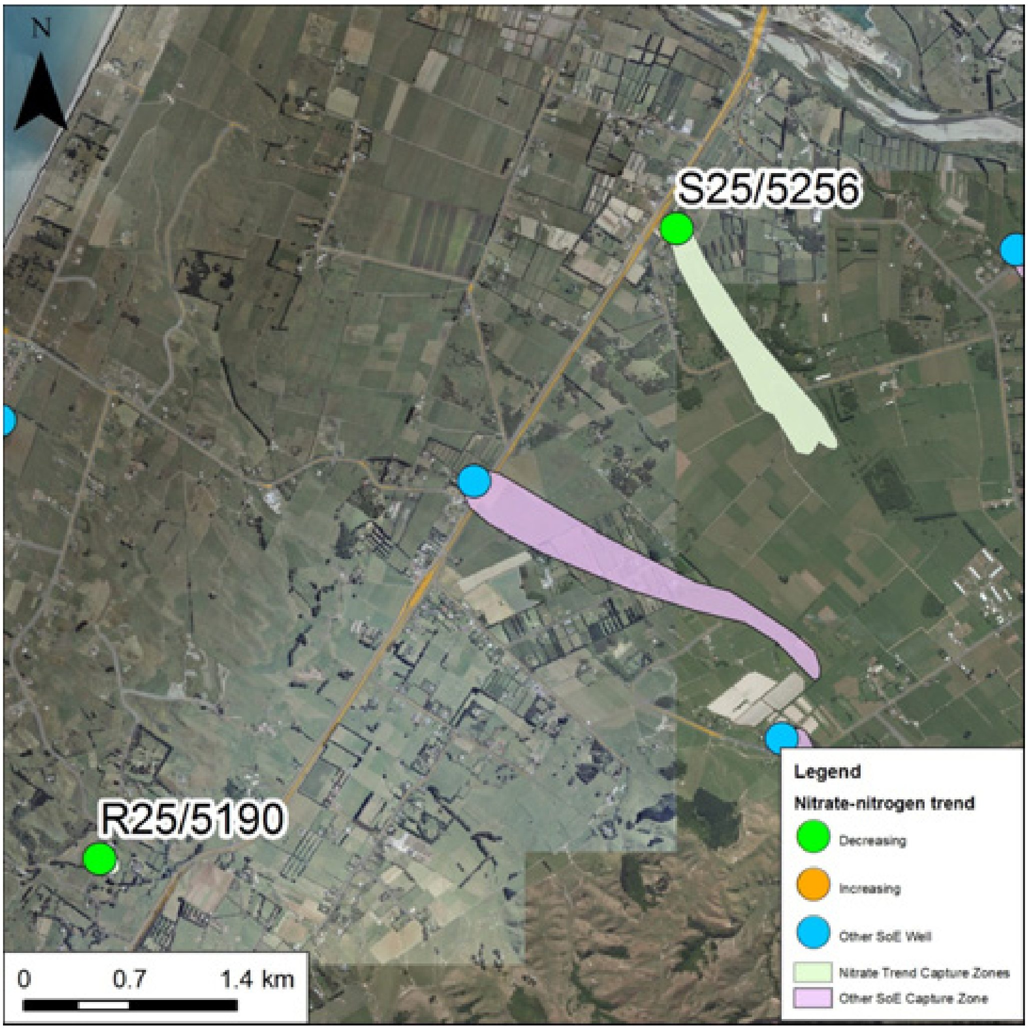

Figure C3: Kapiti (Coastal/Hautere) Source Capture Zones

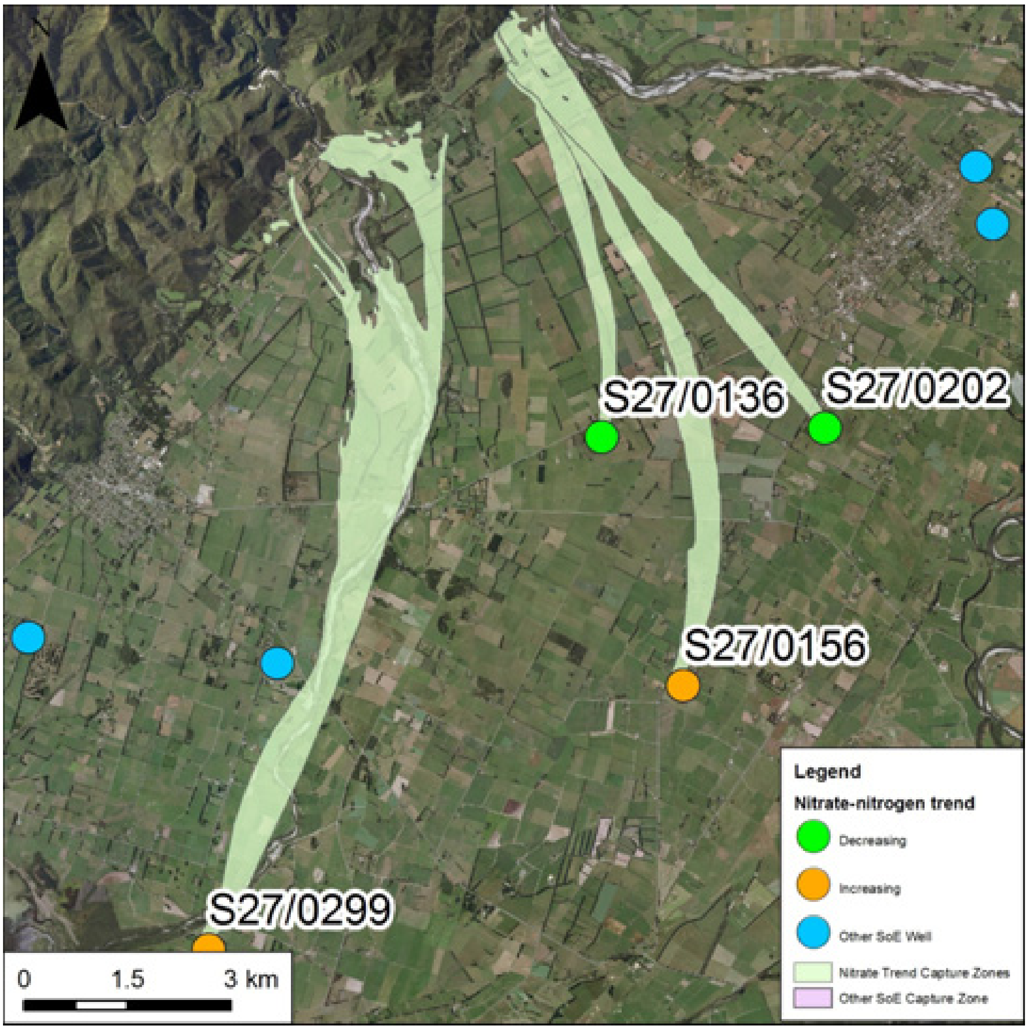

Figure C4: Tauherenikau / Lake Basin Source Capture Zones

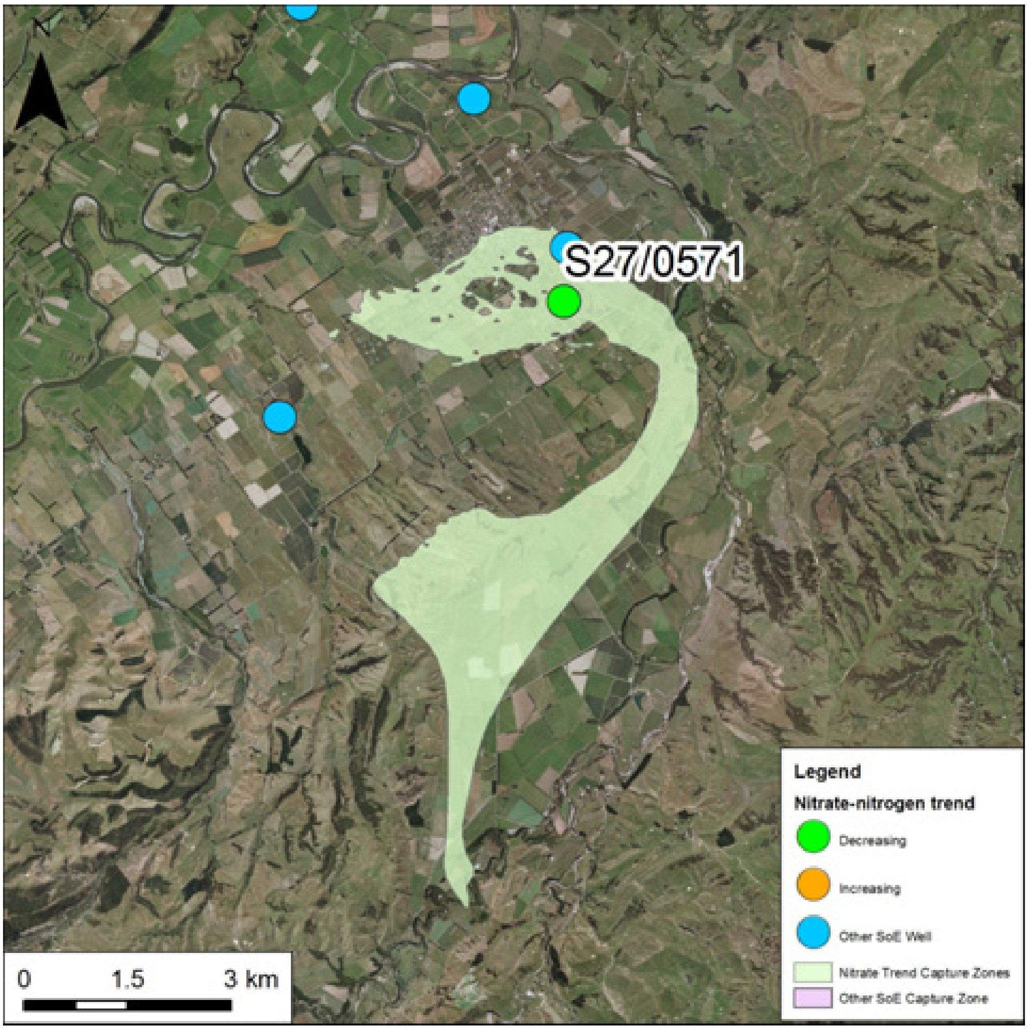

Figure C5: Martinborough Terraces Source Capture Zones

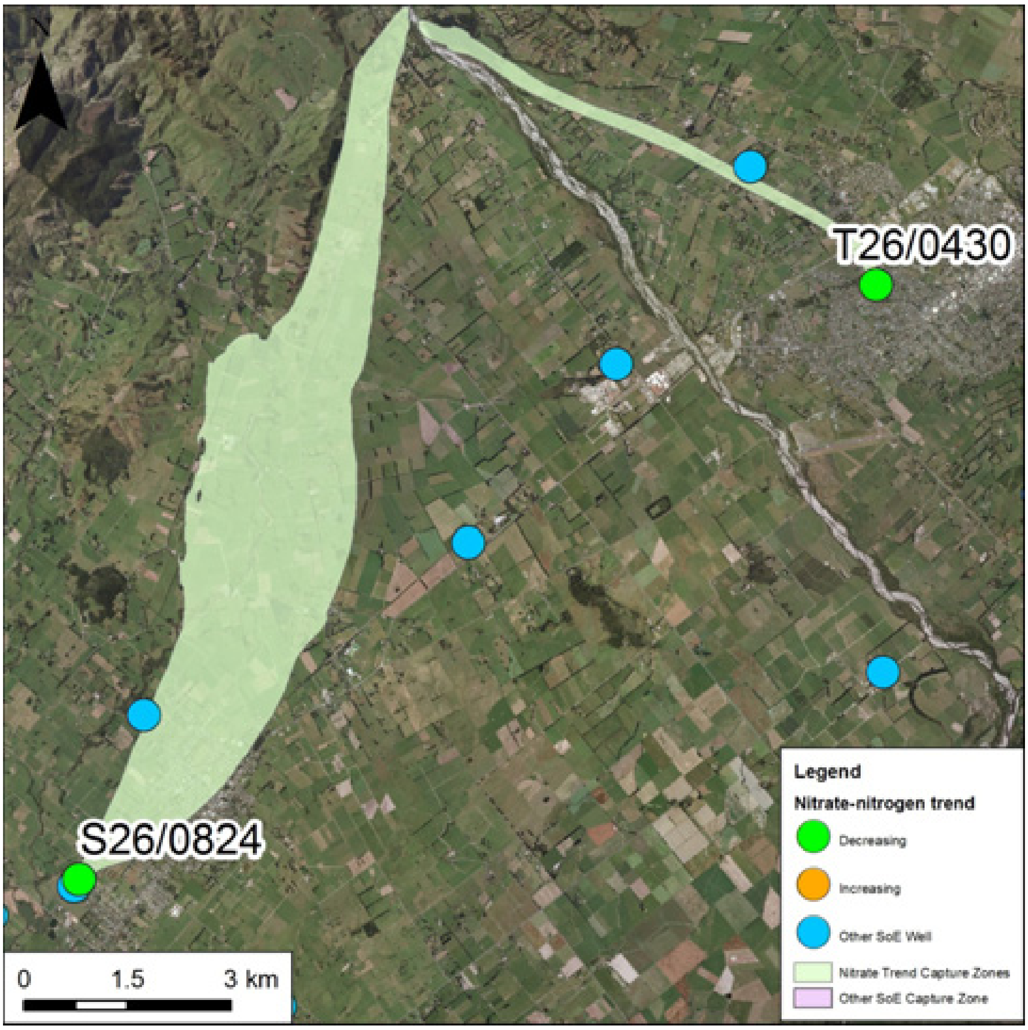

Figure C6: Mangatarere / Waingawa Source Capture Zones

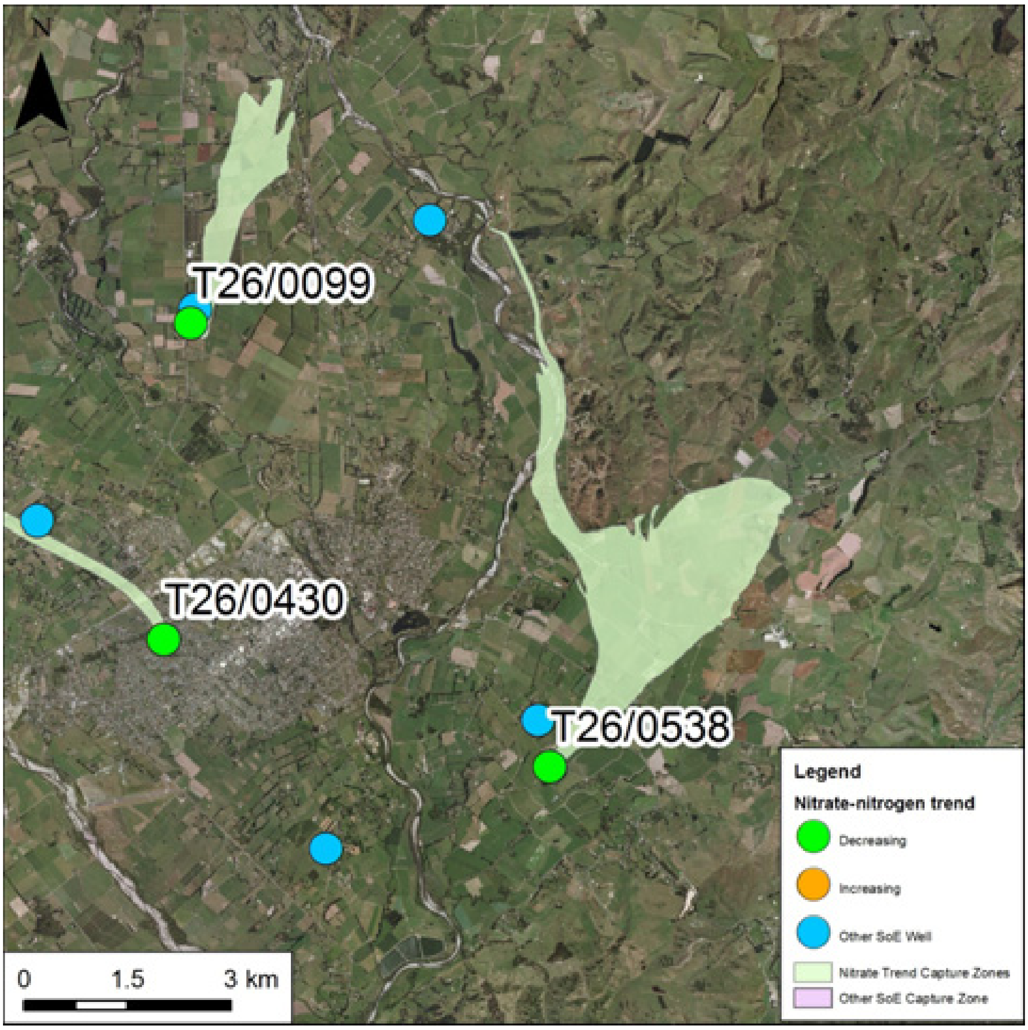

Figure C7: Waipoua / Te Ore Ore Source Capture Zones

Figure C8: Riversdale Source Capture Zone (not delineated)

Appendix D: Land use tables

Table D1: Land use statistics of sites with increasing trends

Zone	**S27/0156 - Tauherenikau**			**S27/0299 - Lake Basin**		
Land use	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**
Arable	0.00	0.16	0.16	0.00	0.00	0.00
Beef	94.63	44.08	-50.55	358.29	100.69	-257.60
Dairy	28.01	40.24	12.23	147.03	183.01	35.98
Deer	0.00	0.00	0.00	0.00	0.00	0.00
Drystock	0.00	4.73	4.73	35.49	0.00	-35.49
Forest	0.00	0.00	0.00	0.00	10.37	10.37
Fruit growing	0.00	0.00	0.00	0.00	0.00	0.00
Goat	0.00	0.00	0.00	0.00	0.00	0.00
Grazing	38.42	43.06	4.64	22.58	4.92	-17.66
Horticulture	0.00	0.00	0.00	0.00	5.48	5.48
Lifestyle	8.43	42.23	33.79	0.00	4.77	4.77
Native bush	0.00	0.00	0.00	0.00	0.00	0.00
New record	0.00	0.00	0.00	0.00	0.00	0.00
Not farmed	0.00	0.00	0.00	0.00	0.00	0.00
Plant nurseries	0.00	0.00	0.00	0.00	0.00	0.00
Other planted types	0.00	0.00	0.00	0.00	0.00	0.00
Ostrich	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00	12.74	12.74
Poultry	0.00	0.00	0.00	0.00	0.00	0.00
Sheep	80.23	31.86	-48.38	93.93	15.84	-78.09
Sheep and beef	24.69	80.72	56.03	82.61	396.30	313.69
Tourism	0.00	0.00	0.00	0.00	0.00	0.00
Unspecified	13.34	0.00	-13.34	0.00	0.00	0.00
Vegetable	0.00	0.00	0.00	0.00	0.00	0.00
Viticulture	0.00	0.00	0.00	0.00	0.00	0.00
Blank (not in database)	38.14	38.84	0.69	193.53	199.34	5.81
Grand Total	**325.90**	**325.90**	**0.00**	**933.47**	**933.47**	**0.00**

Table D2: Land use statistics of sites with decreasing trends

Zone	R25/5190 - Coastal			R27/1265 – Lower Hutt			S25/5256 - Hautere		
Land use	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**
Arable	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Beef	2.18	2.18	0.00	0.00	0.00	0.00	14.98	9.85	-5.12
Dairy	0.00	0.00	0.00	0.00	0.00	0.00	17.90	17.67	-0.23
Deer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Drystock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fruit growing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.27
Goat	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	-0.23
Grazing	0.00	0.00	0.00	0.00	0.00	0.00	0.42	0.00	-0.42
Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lifestyle	0.00	0.00	0.00	0.00	1.86	1.86	0.00	8.27	8.27
Native bush	0.00	0.00	0.00	1.09	1.12	0.03	0.00	0.00	0.00
New record	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Not farmed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant nurseries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other planted types	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ostrich	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	-0.69
Sheep	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sheep and beef	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tourism	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unspecified	0.00	0.00	0.00	0.54	0.00	-0.54	0.00	0.00	0.00
Vegetable	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.99
Viticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blank (not in database)	0.50	0.50	0.00	351.73	350.37	-1.36	7.42	4.59	-2.82
Grand Total	**2.68**	**2.68**	**0.00**	**353.36**	**353.36**	**0.00**	**41.65**	**41.65**	**0.00**

Table D3: Land use statistics of sites with decreasing trends

Zone	S26/0824 - Mangatarere			S27/0136 - Tauherenikau			S27/0202 - Tauherenikau		
Land use	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**
Arable	115.00	1.46	-113.54	0.00	0.00	0.00	0.00	0.00	0.00
Beef	117.02	96.36	-20.66	94.86	0.00	-94.86	45.58	63.46	17.88
Dairy	763.47	778.35	14.88	31.56	58.86	27.29	48.26	106.96	58.70
Deer	29.25	0.00	-29.25	0.00	0.00	0.00	0.00	0.00	0.00
Drystock	9.80	16.54	6.74	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0.25	1.34	1.09	0.00	0.00	0.00	0.00	0.00	0.00
Fruit growing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Goat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grazing	3.80	119.93	116.13	1.07	1.43	0.36	41.21	41.01	-0.20
Horticulture	2.66	0.00	-2.66	5.03	5.03	0.01	0.00	0.00	0.00
Lifestyle	13.42	210.06	196.64	0.00	1.50	1.50	0.00	0.33	0.33
Native bush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New record	10.89	4.05	-6.84	0.00	0.00	0.00	0.00	0.00	0.00
Not farmed	0.00	2.09	2.09	0.00	0.00	0.00	0.00	0.00	0.00
Plant nurseries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other planted types	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ostrich	4.39	3.13	-1.26	0.00	0.00	0.00	0.00	0.00	0.00
Other	16.44	0.00	-16.44	0.48	0.00	-0.48	0.00	0.00	0.00
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	-0.04
Sheep	309.88	230.75	-79.13	16.84	16.47	-0.37	44.49	11.81	-32.68
Sheep and beef	34.86	74.74	39.89	0.00	94.70	94.70	51.07	62.93	11.86
Tourism	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Unspecified	49.15	46.44	-2.71	0.00	0.00	0.00	0.00	0.00	0.00
Vegetable	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blank (not in database)	416.25	311.28	-104.97	30.69	2.53	-28.16	74.98	19.12	-55.86
Grand Total	**1896.55**	**1896.55**	**0.00**	**180.52**	**180.52**	**0.00**	**305.63**	**305.63**	**0.00**

Table D4: Land use statistics of sites with decreasing trends

Zone	S27/0571 - Mtb Terraces			T26/0099 - Waipoua			T26/0430 - Waingawa		
Land use	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**	**2001**	**2012**	**Change (ha)**
Arable	0.00	10.23	10.23	0.00	0.00	0.00	0.00	0.00	0.00
Beef	157.30	145.64	-11.66	17.08	12.18	-4.91	12.22	3.22	-9.00
Dairy	10.17	0.00	-10.17	0.00	0.00	0.00	0.00	0.00	0.00
Deer	25.54	0.60	-24.95	0.00	0.00	0.00	37.17	43.28	6.11
Drystock	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Forest	0.00	2.47	2.47	0.00	0.17	0.17	0.00	0.00	0.00
Fruit growing	18.18	20.34	2.16	2.24	0.00	-2.24	2.31	2.70	0.39
Goat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grazing	0.00	13.60	13.60	41.73	0.97	-40.76	0.00	0.00	0.00
Horticulture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lifestyle	1.42	67.02	65.60	2.57	17.16	14.59	10.40	32.45	22.05
Native bush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
New record	0.00	6.10	6.10	0.00	0.00	0.00	0.00	0.00	0.00
Not farmed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Plant nurseries	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other planted types	0.00	1.16	1.16	0.00	0.00	0.00	0.00	0.00	0.00
Ostrich	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	38.41	38.41	0.00	0.00	0.00	0.04	0.08	0.04
Poultry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sheep	584.84	76.46	-508.37	72.36	11.94	-60.41	18.03	16.02	-2.01
Sheep and beef	165.45	493.29	327.85	49.90	107.10	57.21	0.62	1.51	0.89
Tourism	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.39	4.39
Unspecified	6.24	0.00	-6.24	4.66	0.00	-4.66	6.58	0.00	-6.58
Vegetable	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Viticulture	0.87	175.35	174.47	1.54	43.25	41.70	0.00	0.00	0.00
Blank (not in database)	446.39	365.72	-80.66	2.10	1.40	-0.69	84.25	67.97	-16.28
Grand Total	**1416.40**	**1416.40**	**0.00**	**194.17**	**194.17**	**0.00**	**171.62**	**171.62**	**0.00**

Table D5: Land use statistics of sites with decreasing trends

Zone	T26/0538 - Te Ore Ore		
Land use	**2001**	**2012**	**Change (ha)**
Arable	0.00	0.00	0.00
Beef	101.03	51.36	-49.67
Dairy	195.42	224.44	29.02
Deer	2.62	6.90	4.28
Drystock	0.00	0.00	0.00
Forest	0.73	0.72	0.00
Fruit growing	0.00	2.66	2.66
Goat	0.00	0.00	0.00
Grazing	0.90	4.25	3.35
Horticulture	4.22	0.00	-4.22
Lifestyle	0.00	23.50	23.50
Native bush	0.00	0.00	0.00
New record	0.00	10.22	10.22
Not farmed	0.00	0.00	0.00
Plant nurseries	4.16	4.17	0.01
Other planted types	0.00	0.00	0.00
Ostrich	0.00	0.00	0.00
Other	0.00	0.00	0.00
Poultry	0.00	0.00	0.00
Sheep	165.47	26.33	-139.15
Sheep and beef	116.49	269.69	153.20
Tourism	0.00	0.00	0.00
Unspecified	13.05	0.00	-13.05
Vegetable	0.00	0.00	0.00
Viticulture	0.00	2.06	2.06
Blank (not in database)	146.30	124.09	-22.22
Grand Total	**750.40**	**750.40**	**0.00**