Kapiti Coast groundwater quality investigation, 2008

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Executive summary

This report summarises the results of a groundwater quality investigation undertaken on the northern Kapiti Coast in late 2008. The investigation targeted the impacts on groundwater quality, particularly nutrient concentrations, of intensive farming and horticultural development as well as the expansion of properties at Te Horo Beach serviced by on-site wastewater treatment systems.

Groundwater samples from 31 bores were tested for dissolved nutrients and faecal indicator bacteria. Results were compared against the Drinking Water Standard for New Zealand (DWSNZ 2005) maximum acceptable values (MAV) and guidelines.

The investigation found that nitrate-nitrogen contamination of groundwater exists to various degrees in the area studied. The most widespread contamination is present in unconfined shallow groundwater in the Hautere groundwater zone, with isolated areas of contamination identified in the unconfined aquifer of the Waitohu groundwater zone. For example, the highest individual nitrate-nitrogen concentration (11 mg/L) was recorded in a bore in the Waitohu groundwater zone. A number of bores recorded nitrate-nitrogen concentrations of at least half the MAV (11.3 mg/L).

The investigation also found:

- Dissolved reactive phosphorus concentrations were generally low, with samples from just seven bores having concentrations above 0.1 mg/L. Most of these bores were located in the Coastal groundwater zone.

- Ammoniacal-nitrogen concentrations did not exceed the DWSNZ (2005) guideline value of 1.5 mg/L for odour and taste thresholds.

- Nitrite-nitrogen concentrations were below the DWSNZ (2005) MAV of 0.06 mg/L in all borewater samples, with concentrations ranging from less than the laboratory detection limit (0.002 mg/L) to 0.039 mg/L.

- Counts of *Escherichia coli (E. coli)* in all borewater samples were below the DWSNZ (2005) MAV of <1 cfu/100mL except in samples from two bores which had counts of 1 cfu/100mL and 2 cfu/100mL. Only one of these bores is used as a potable water supply.

Comparison of results from the 2008 targeted investigation with data collected in a similar investigation conducted in 1996 indicates that the same areas of the Kapiti Coast are still affected by elevated groundwater nitrate-nitrogen concentrations. However, many of the bores sampled in 2008 had lower concentrations of nitrate-nitrogen than concentrations measured in these areas in 1996. Trend analysis undertaken on groundwater data from 10 bores over 1993 to 2009 confirmed statistically significant decreases (0.28-0.31 mg/L/yr) in nitrate-nitrogen concentrations in three bores located in areas of horticulture, although there was also one statistically significant increase (0.04 m/L/yr) in a bore located at Te Horo Beach settlement.

Overall, areas which historically had nitrate-nitrogen contamination of groundwater remain contaminated. Many of these areas are in or downgradient of intensive land use (horticulture and agriculture) and consented discharges to land (animal and sewage) suggesting that these land use and activity types are contributing to groundwater contamination. Also, a number of areas downgradient of consented discharges and intensive land use practices were not monitored, and limited monitoring has been conducted in shallow bores. Further monitoring is essential in understanding contamination flow paths and the impacts of land use on shallow aquifers.

In general, the Hautere and Waitohu groundwater zones are still areas of concern as nitrate-nitrogen concentrations in some bores in these zones remain highly elevated (7–11.3 mg/L) and piezometric surveys suggest that there is potential for nitrate to migrate into surface water bodies with the flow of groundwater. Soil nutrient loadings and wastewater application rates must therefore be assessed carefully, particularly in areas of intensive land use.

A number of recommendations have been made relating to future monitoring and investigations that should improve our ability to detect and understand sources of groundwater contamination on the northern Kapiti Coast.

Contents

1. Introduction

Routine groundwater quality monitoring in the Wellington region, carried out as part of the Groundwater State of the Environment (GWSoE) programme, has highlighted elevated nitrate concentrations (>3 mg/L as nitrate-nitrogen) in some areas, including the Hautere, Coastal, Otaki, Te Ore Ore, Upper Plain, Carterton, Parkvale, East Taratahi, Moroa, Matarawa and South Featherston groundwater zones (Jones & Baker 2005). As elevated nitrate concentrations in groundwater are potentially hazardous to human health and can impact on surface water quality, Greater Wellington Regional Council (Greater Wellington) has been undertaking targeted groundwater quality investigations to determine the extent of nitrate contamination in selected “at-risk” areas.

This report summarises the results of a groundwater quality investigation undertaken on the northern Kapiti Coast during November and December 2008. The investigation targeted the impacts on groundwater quality (in particular nitrate contamination) of intensive farming and horticultural development as well as the expansion of properties at Te Horo Beach serviced by on-site wastewater treatment systems. Impacts were assessed against the Drinking Water Standard for New Zealand (DWSNZ 2005) and mainly focused on groundwater concentrations of nitrate-nitrogen.

In furthering our understanding of the extent and likely causes of poor groundwater quality in the region, targeted studies provide important information that is needed in order to fulfil Objectives 4.1.4 and 4.1.6 of Greater Wellington’s Regional Plan for Discharges to Land (Wellington Regional Council 1999a). These objectives seek a significant reduction in contamination of surface water, groundwater and coastal water from discharges of human effluent to land (Objective 4.1.4), and a significant reduction in non-point source pollution of surface water and groundwater from agricultural activities (Objective 4.1.6).

1.1 Report outline

An overview of the geology and hydrology of the Kapiti Coast is presented in Section 2. Past and current last uses are outlined in Section 3 and a summary of previous groundwater quality investigations is provided in Section 4. An overview of the 2008 study area, sampling sites, methods and analysis is presented in Section 5. Groundwater quality sampling results from the 31 bores and the findings of temporal trend analysis conducted on GWSoE data are also reported in Section 5. A discussion of the results follows in Section 6 and overall conclusions and recommendations are presented in Section 7.

1.2 Nomenclature

From this point forward, nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, ammoniacal nitrogen, dissolved reactive phosphorus and *Escherichia coli* are referred to in the text as nitrate, nitrite, TKN, ammonia, DRP and *E. coli* respectively.

2. Kapiti Coast – geology and hydrology

2.1 Physical setting

The Kapiti Coast is located at the base of the Tararua Range on the west coast of the North Island (Figure 2.1). It is a relatively narrow coastal plain that spans from Paekakariki to just north of Otaki and is intersected by a number of rivers and streams that drain west from the Tararua Range. Extensive sand dune systems create the undulating topography which dominates much of the coastal landscape, while the foothills of the Tararua Range give way to flat plains that dominate the inland topography. The 2008 targeted groundwater quality investigation was conducted in northern Kapiti and includes the Te Horo, Otaki and the area north of Otaki (Figure 2.1).

In recent years the Kapiti Coast District has seen a rapid expansion in the number of lifestyle blocks and coastal subdivision developments. An increase in urbanisation has seen a shift away from traditional dairy and horticultural land use practices in the area.

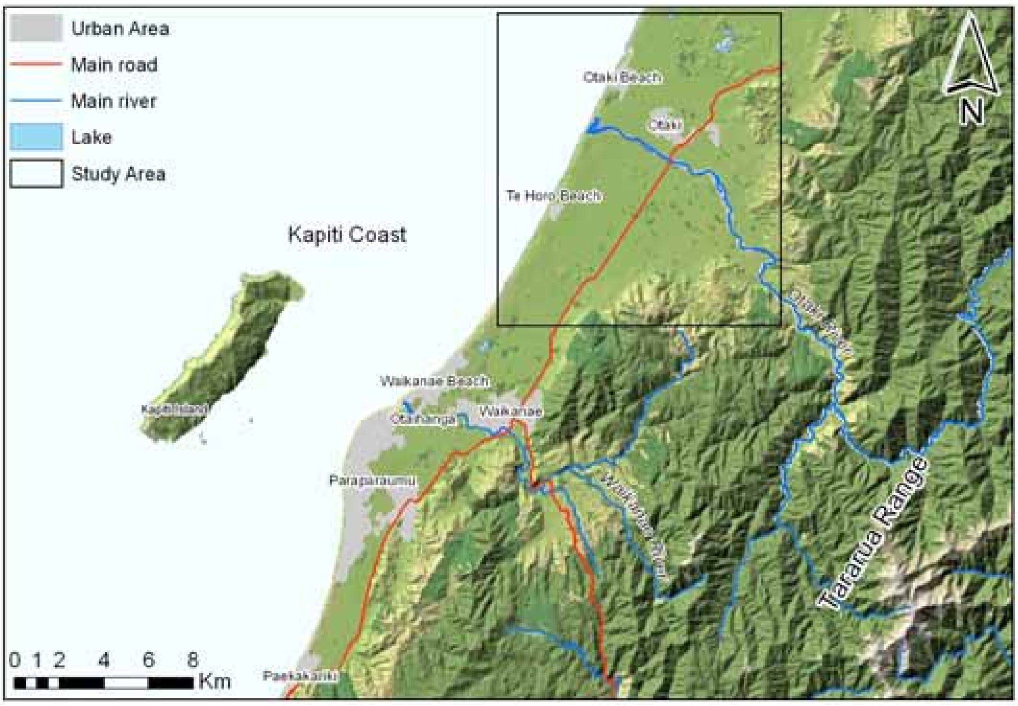

Figure 2.1: The Kapiti Coast extends from Paekakariki to just north of Otaki. The 2008 groundwater quality investigation was undertaken within the area defined by the black square.

2.2 Geology

The geological sequence of the Kapiti Coast comprises alluvial gravel, sand and silt overlain with marine sediments. The Tararua Range was uplifted by tectonic movement during the Quaternary while eustatic sea level change reworked alluvium and deposited material along the coast line (Kampman & Caldwall 1985). Figure 2.2 is a generalised conceptual model of the geology and aquifer systems of the Kapiti Coast.

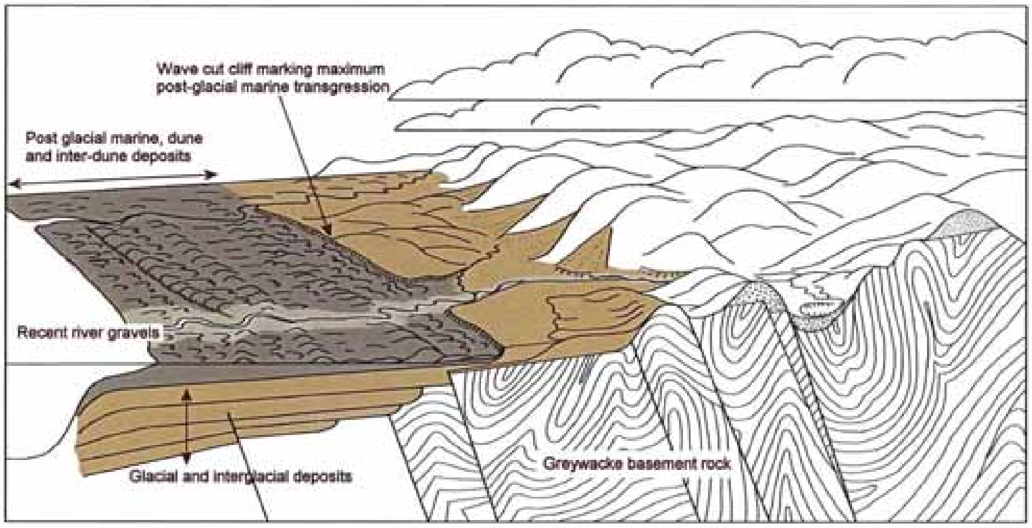

Figure 2.2: General cross-section of the Kapiti Coast geology
(Source: Jones & Baker 2005)

In glacial periods the sea levels were approximately 200 metres below present day level and the coastline approximately 10km seaward of the present day coast. Glaciers eroded the Tararua Range and alluvial material was rapidly deposited on the coastal plains by rivers. During temperate interglacial and postglacial periods, vegetation re-established at higher altitudes and the amount of material eroded from the Tararua Range was reduced. Rivers were able to entrench into former alluvial deposits on the upper plains while the coastal environment reworked alluvial deposits in the lower reaches of the river systems. Cycles of climate change during the Quaternary resulted in sequences of poorly sorted material (rapidly deposited during glacial periods) alternating with reworked alluvium (deposited during interglacial periods) (Hughes 1997, Kampman & Caldwall 1985).

A wave-cut cliff which runs the length of the Kapiti Coast indicates the maximum extent of sea level rise that occurred c.6,500 year BP (Hughes 1997) (Figure 2.2). Transgression of the sea over the coastal plain enabled the deposition of beach and marine sediments over earlier alluvial material. Sand dunes, inter-dunal swamps and beach sand deposits formed in the wake of the receding sea level high and are still a part of the landscape seen today (Hughes 1997, Kampman & Caldwall 1985).

2.3 Hydrogeology

Jones & Baker (2005) broadly classified the hydrogeology of the Kapiti Coast aquifers into three groups based on their environment of deposition:

- Glacial and inter-glacial deposits;
- Post-glacial beach and dune sand deposits; and
- Recent river gravels.

The glacial and interglacial deposits overlie the basement rock and form a thick layered semi-confined to confined aquifer system of poorly sorted and stratified clay-bound gravels and sands. The aquifer spans the length of the coast and has moderate transmissivity values of 500-1000 m^2/day (Jones & Baker 2005). Recharge is thought to be mainly from rainfall infiltration through soil, particularly on the eastern margin of the coast at the base of the Tararua Range where aquifers are less confined. Locally significant river recharge is associated with losses from the Waikanae and Otaki rivers.

Postglacial sand deposits form a low-yielding, unconfined aquifer which becomes semi-confined with depth as the aquifer approaches the coast. The aquifer is up to 50 metres thick at the coast and pinches out to a thin layer towards the wave-cut cliff to the east. The postglacial aquifer system also includes a coastal dune belt where limited drainage has resulted in the formation of inter-dunal wetlands. Recharge is thought to be mainly from rainfall (Jones & Baker 2005).

Recent river gravel deposits form the relatively high-yielding unconfined aquifers in the alluvial flood plain around the main Kapiti rivers. The gravels were reworked by the rivers during the interglacial and postglacial period and have a direct hydraulic connection with surface water.

There are four groundwater zones within the 2008 groundwater investigation area (Figure 2.3). Each of these zones is described below.

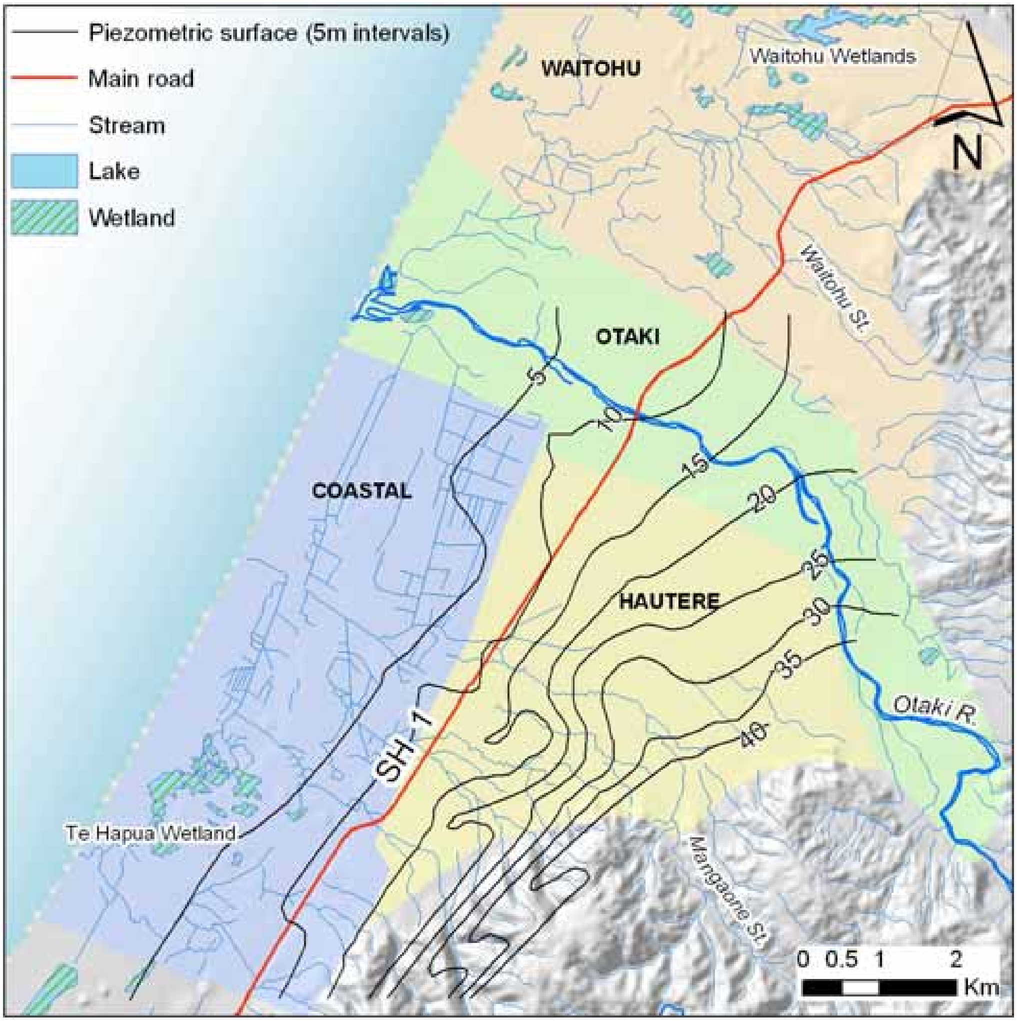

Figure 2.3: Piezometric contours of the Kapiti Coast groundwater zones. Groundwater flow is towards the coast in the Hautere, Coastal and Otaki groundwater zones.
(Source: WRC 1994)

2.3.1 Waitohu groundwater zone

The Waitohu groundwater zone is located north of the Otaki River. Sediment within this zone consists of remnant alluvial fan deposits eroded from the Tararua Range and laid down during the Otarian glaciation. The groundwater zone is generally defined by a thick succession of clay-bound gravel layers separated by discontinuous silt and clay lenses that extend to the basement rock (>200m). Transmissivities are relatively low (50 – 400 m^2/day) except in the area close to the Waitohu Stream where higher transmissivities (2,500 – 4,000 m^2/day) are due to the permeable river gravels (Hughes 1997, Kampman & Caldwall 1985).

Analysis of bores logs identified five separate aquifers (WRC 1994):

- Aquifer one is an unconfined aquifer 2-10 metres below the ground surface and consists of permeable river gravels. Groundwater level in this aquifer is influenced by stream flow. Aquifer one is underlain by clay-bound gravels.

- Aquifer two is a semi-confined aquifer 20-30 metres below the ground surface. The aquifer consists of brown gravel and sand with some blue sand. Transmissivities are <100 m^2/day. Discontinuous layers of peat, clay, clay-bound gravels and sand form the semi-confining layers in this aquifer.

- Aquifer three is a confined aquifer 40-45 metres below the ground surface. It consists of blue gravels and sand underlain by peat and clay. The aquifer is generally low-yielding and has poor quality water.

- Aquifer four is a confined aquifer at 50-60 metres below ground surface. Sediments consist of a sand layer with some blue gravels.

- Aquifer five is a low-yielding aquifer between 60-75 metres below ground surface. It consists of poorly sorted clay-bound gravels and sands.

Recharge to the shallow aquifers is via losses from the Waitohu Stream and from rainfall infiltration. Deeper aquifers are recharged by rainfall and runoff close to the Tararua foothills as well as leakage from overlying aquifers. Groundwater flow is thought to be towards the coast (WRC 1994).

2.3.2 Otaki groundwater zone

The Otaki groundwater zone is limited to a narrow area that extends along the length of the Otaki River and encompasses the river's floodplain. Otaki aquifers consist of eroded gravels, silts and sand from the Tararua Range. Deposits have been reworked by the Otaki River and become better sorted with distance from deposition. Beach processes and marine deposits have influenced the geology downstream of the Otaki River by reworking and mixing with alluvial material brought down by the Otaki River (Hughes 1997, Kampman & Caldwall 1985, WRC 1994).

There are three identified aquifers in the Otaki groundwater zone (WRC 1994):

- Aquifer one is an unconfined aquifer extending 11 metres below the ground surface which formed as the Otaki River entrenched into older glacial deposits. The aquifer consists predominantly of brown river gravels with some silt and sand overlain by four metres of sands, silts and clays deposited during flood events in the Otaki River. Alluvial material was thoroughly reworked during the river's entrenchment and this has resulted in relatively high transmissivity values (around 4,500 m^2/day). This aquifer also has a strong hydraulic connection to the Otaki River and groundwater levels are strongly influenced by river levels.

- Aquifer two is a semi-confined aquifer between 11-19 metres below the ground surface that comprises low permeable sands.

- Aquifer three is also a semi-confined aquifer between 19-35 metres below the ground surface and consists of sand and gravel layers separated by silty gravels. Groundwater levels are believed to be dependent on flow in the Otaki River.

Deeper aquifers exist below 35 metres. These aquifers appear to be confined and artesian. Recharge is primarily due to significant losses from the Otaki River. For example, it is estimated that 10% of flow in the Otaki River is lost to groundwater as the river flows to the sea (Hughes 1997). Recharge to the deeper aquifers may be from infiltration of river water and rainfall in the upper reaches of the Otaki groundwater zone (WRC 1994). Groundwater flow is towards the coast (refer Figure 2.3).

2.3.3 Hautere groundwater zone

The Hautere groundwater zone is located south of the Otaki River and extends in a west to east direction from State Highway 1 to the Tararua Range. An unconfined aquifer exists to a depth of 30 metres and consists of alluvial fan deposits eroded from the Tararua Range during the Otarian glaciation and clay-bound gravels divided by discontinuous lenses of silts and clays. Semi-confined aquifers exist below depths of 30 metres but these aquifers appear to have a high degree of connectivity with the shallow aquifer above (Kampman & Caldwall 1985, WRC 1994). Monitoring has shown groundwater levels to be similar in bores of significantly different depths (WRC 1994).

Kampman and Caldwell (1985) divided the Hautere groundwater zone into three layers based on groundwater chemistry:

- Layer one is 10–30 metres below ground surface, defined by groundwater with high concentrations of nitrate-nitrogen. This layer has slightly higher transmissivities than the other two layers.
- Layer two is 40-70 metres below ground surface, defined by groundwater with high concentrations of iron.
- Layer three is 90-150 metres below ground surface, defined by groundwater with high concentrations of boron.

In general, rainfall is the main source of recharge in the Hautere groundwater zone with minor contributions from runoff from the Taraura Range. Vertical leakage distributes water to the lower layers of the aquifer (WRC 1994). The general direction of groundwater flow is towards the coast except in the vicinity of the Otaki River where groundwater flows slightly towards the river terraces (refer Figure 2.3).

2.3.4 Coastal groundwater zone

The Coastal groundwater zone is located south of the Otaki River and extends in a west to east direction from the coast to State Highway 1. This zone has been described as a seaward extension of the Hautere groundwater zone (Hughes 1997) as the hydrogeological units at depth in the Coastal groundwater zone are similar to the units in the Hautere groundwater zone. In the last 14,000 years 40 metres of gravel, sand, silt and swamp material have been laid down over the older Otarian alluvial fan deposits. The boundary between the Hautere and Coastal groundwater zones is denoted by a wave-cut cliff which marks the maximum extent of the sea level high (Hughes 1997, Kampman & Caldwall 1985).

Four aquifers have been identified in the Coastal groundwater zone (WRC 1994):

- Aquifer one is a generally unconfined aquifer (becoming semi-confined with depth), 5-30 metres below the ground surface. Sediment consists of brown and blue sands and gravels.
- Aquifer two is a confined aquifer 35-56 metres below the ground surface, which is thought to dip towards the coastline and towards the south. Aquifer sediments consist of brown gravels.
- Aquifer three is a confined aquifer located 65-110 metres below the ground surface. Aquifer sediments vary between layers of sand and gravels.
- Aquifer four is a confined aquifer located 164-172 metres below the ground surface. Aquifer sediments comprise brown gravels.

Transmissivity in the Coastal groundwater zone ranges from <100 m^2/day to 200 m^2/day (WRC 1994). Groundwater flow is towards the coast with discharge from the confined aquifers thought to be offshore (refer Figure 2.3). The shallow aquifer is possibly affected by tidal influences (WRC 1994). A number of springs discharge along the wave-cut cliff and flow into drainage systems, the Mangaone Stream or wetland systems (Cussins 1994). Recharge to shallow aquifers is from rainfall infiltration while flow from the Hautere groundwater zone is thought to recharge the deeper Coastal aquifers (WRC 1994). The Mangaone Stream runs through the Hautere and Coastal groundwater zones but gauging of the stream suggests that the stream does not contribute to groundwater recharge (Cussins 1994).

2.4 Hydraulic gradient and direction of flow

Piezometric surveying was conducted in March 1993 and suggests that groundwater flows towards the coast in the Hautere, Coastal and Otaki groundwater zones (refer Figure 2.3). The contours flatten towards the coast with some divergence to the south to possible surface water discharge areas around the Mangaone Stream, Te Hapua wetland and numerous land drains. The piezometric surface is also possibly influenced by the losing reach of the Otaki River. There has been no piezometric surveying of the Waitohu groundwater zone but it is thought to have a similar groundwater flow pattern to that of the Coastal and Hautere zones, with several prominent wetlands.

Bores located in the deeper aquifers within the Coastal and Otaki groundwater zones tend to have a piezometric head closer to the ground surface than bores located in the shallow aquifers (Table 2.1). This suggests that aquifers in these groundwater zones have increasing confinement with depth with an upward pressure gradient; this could limit the movement of contaminants from shallow aquifers to deeper aquifers.

Table 2.1: Vertical hydraulic gradient (VGC) in the Coastal, Hautere, Waitohu and Otaki groundwater zones. Positive VHG suggests that vertical groundwater movement is upwards while negative VHG suggests downward groundwater movement.

Bore Number	Bore Depth (m)	Depth to groundwater (from ground surface) (m)	Groundwater Zone	Aquifer	Vertical Hydraulic Gradient (downward or upward)
R26/6861	7	6.281	Coastal	1	
R25/5123	13	8.926	Coastal	1	
R25/0003	60	2.748	Coastal	2 or 3	Upward
R25/5152	172	0.293	Coastal	4	Upward
S25/5215	20.73	7.073	Hautere	1	
S25/5256	30.78	11.530	Hautere	1	
S25/5200	45.8	7.832	Hautere	2	Downward
R25/5135	93.27	9.212	Hautere	3	Downward
S25/5258	6	2.979	Otaki	1	
R25/5228	31.71	20.535	Otaki	3	
S25/5307	71.93	-0.601	Otaki	4	Upward
S25/5209	96.50	-4.864	Otaki	4	Upward
S25/5332	9.09	0.539	Waitohu	1	
R25/5233	18.70	0.195	Waitohu	2	
S25/5311	27.70	10.270	Waitohu	2	Downward
S25/5355	40	1.219	Waitohu	3	Downward
S25/5320	59.89	13.574	Waitohu	4	Downward

Piezometric heads recorded in deeper bores of the Hautere and Waitohu groundwater zones tend to be further from the ground surface than piezometric heads recorded in shallower bores (Table 2.1). This suggests that there is a downward pressure gradient in the Hautere and Waitohu groundwater zones. These findings support the theory that recharge to the Hautere and Waitohu groundwater zones is from rainfall that infiltrates into the deeper aquifers. Groundwater zones with downward hydraulic pressure gradients are susceptible to the extensive spread of groundwater contamination from shallow to deeper aquifers.

More work is required to better determine the flow path of groundwater within the Kapiti Coast groundwater zones and its effect on shallow groundwater and surface water environments.

2.5 Rainfall and surface water hydrology

Greater Wellington and NIWA monitor rainfall and river flows at several locations in northern Kapiti (Figure 2.4). Analysis of rainfall patterns shows that annual rainfall increases with distance inland, due to the orographic enhancement effect of the Tararua Range (Watts 2005).

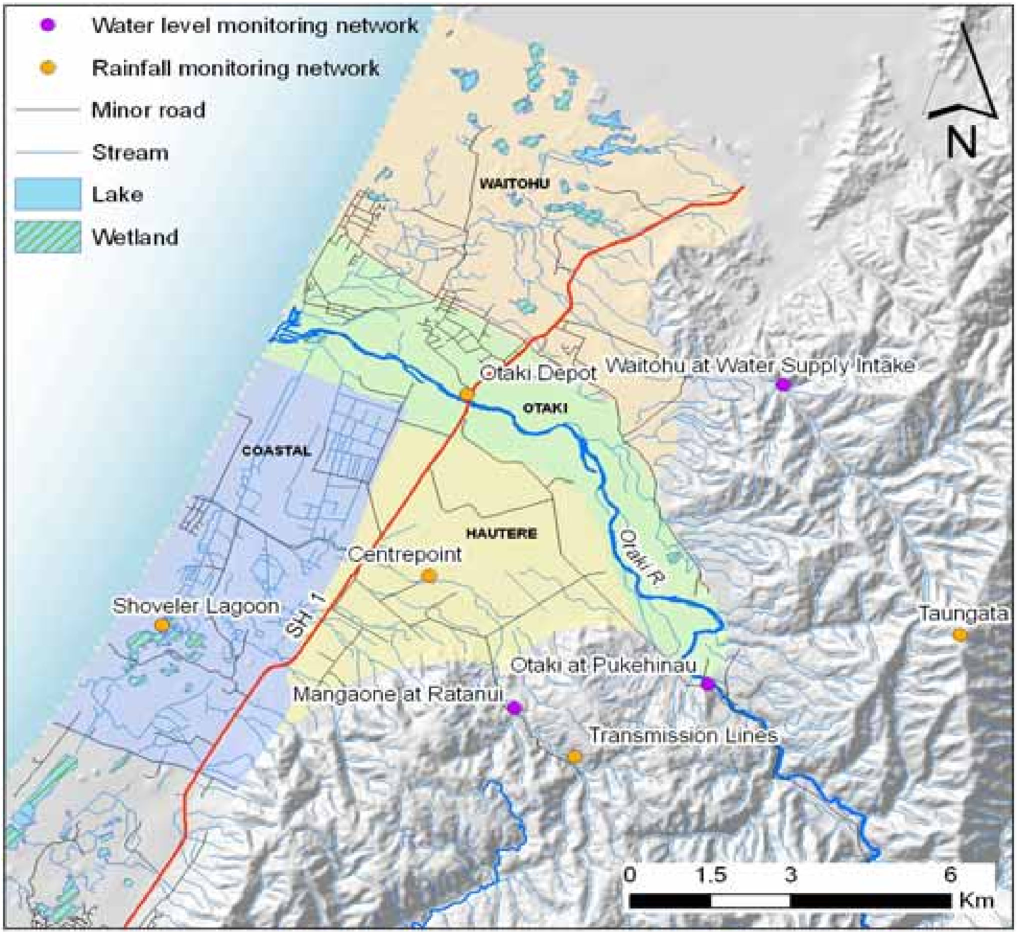

Figure 2.4: Surface water level and rainfall monitoring networks on the Kapiti Coast

Based on Greater Wellington records, mean annual rainfall is between 1,000 mm and 1,100 mm at the coast, increasing to 1,400 mm at the base of the Tararua Range foothills, and up to 5,000 mm in the Tararua Range at the top of the Otaki River catchment. Rainfall tends to peak in winter (June and July) with a secondary peak in October as a result of westerly winds that prevail in springtime. On average, the driest months of the year are March and April. However, overall there is no large seasonal variation in rainfall in this area.

The Otaki River is the main river within the 2008 groundwater quality investigation area. Monthly average flow in the Otaki River is generally lowest in March or April, and highest in October and November. The peak in flow in late spring is a result of westerly fronts causing heavy rainfall in the Tararua Range. The seasonal flow pattern in the smaller streams of the study area (e.g., Waitohu and Mangaone streams) is similar to that observed in the Otaki River.

As the Otaki River exits the Otaki Gorge onto the coastal plain, it loses water to groundwater; this is the main recharge mechanism for the Otaki groundwater zone. Between the Otaki Gorge and State Highway 1 it is estimated that the river loses in the order of 10,500 m^3/day to 87,000 m^3/day, with further loss occuring downstream of State Highway 1 (WRC 1994). Similarly, concurrent gauging of the Waitohu Stream shows a loss of flow downstream of the state highway, as the stream, along with rainfall, recharges the Waitohu groundwater zone. The mid-reaches of the Waitohu Stream can run dry during years of extreme low flow.

Gauging of flow in the Mangaone Stream indicates that there is little interaction between the stream and the Coastal and Hautere groundwater zones. However, there is an extensive network of farm drains in the area that are not monitored, and therefore it is not known to what extent these recharge or receive flow from, the shallow groundwater systems.

3. Land use and pressures on groundwater quality

This section provides a brief overview of existing and past land use within the 2008 groundwater quality investigation area and other key impacts on groundwater. These include discharges to land and water abstraction. Population growth is also outlined.

3.1 Current land use and discharges to land

Over the last decade there has been a major shift in the management of agricultural wastewater discharges in the Wellington region, with such discharges directed away from surface water bodies and onto land wherever practicable. As a result, there are no longer any authorised (consented) agricultural wastewater discharges to rivers, streams or lakes in the Wellington region. While discharges to land have been promoted to help reduce the impacts on surface water quality and ecology, discharging waste onto land has potential implications for soil and groundwater quality. For example, high application rates of wastewater to land may induce leaching of nutrients, pathogens and other contaminants to groundwater, especially in shallow aquifers in winter when soil moisture levels are high. This can be a cause for concern where the groundwater is used for potable or stock water supply, or if the groundwater enters nearby surface water systems.

Land management practices also have the potential to seriously degrade groundwater quality, especially in shallow aquifers. Land on the Kapiti Coast is used for a number of purposes and land management practices can vary in intensity. As shown in Figure 3.1, a large number of the consented discharges to land are located in or around dairying areas or urban development. These include 39 resource consents for animal waste discharges to land (the majority are dairy effluent discharges), 14 consents for treated sewage or wastewater discharges to land (including treated wastewater from the township of Otaki) and one consent authorising the discharge to land of leachate from Otaki Landfill.

Land cover in the 2008 targeted groundwater investigation study area is predominantly indigenous forest (72%) but most of this forest cover is on the lower foot hills of the Tararua Range. Sheep, beef and deer farming account for 16% of the land use in developed parts of the investigation area while dairy farming accounts for 6.3%. A break down of the major land cover is provided in Appendix 1.

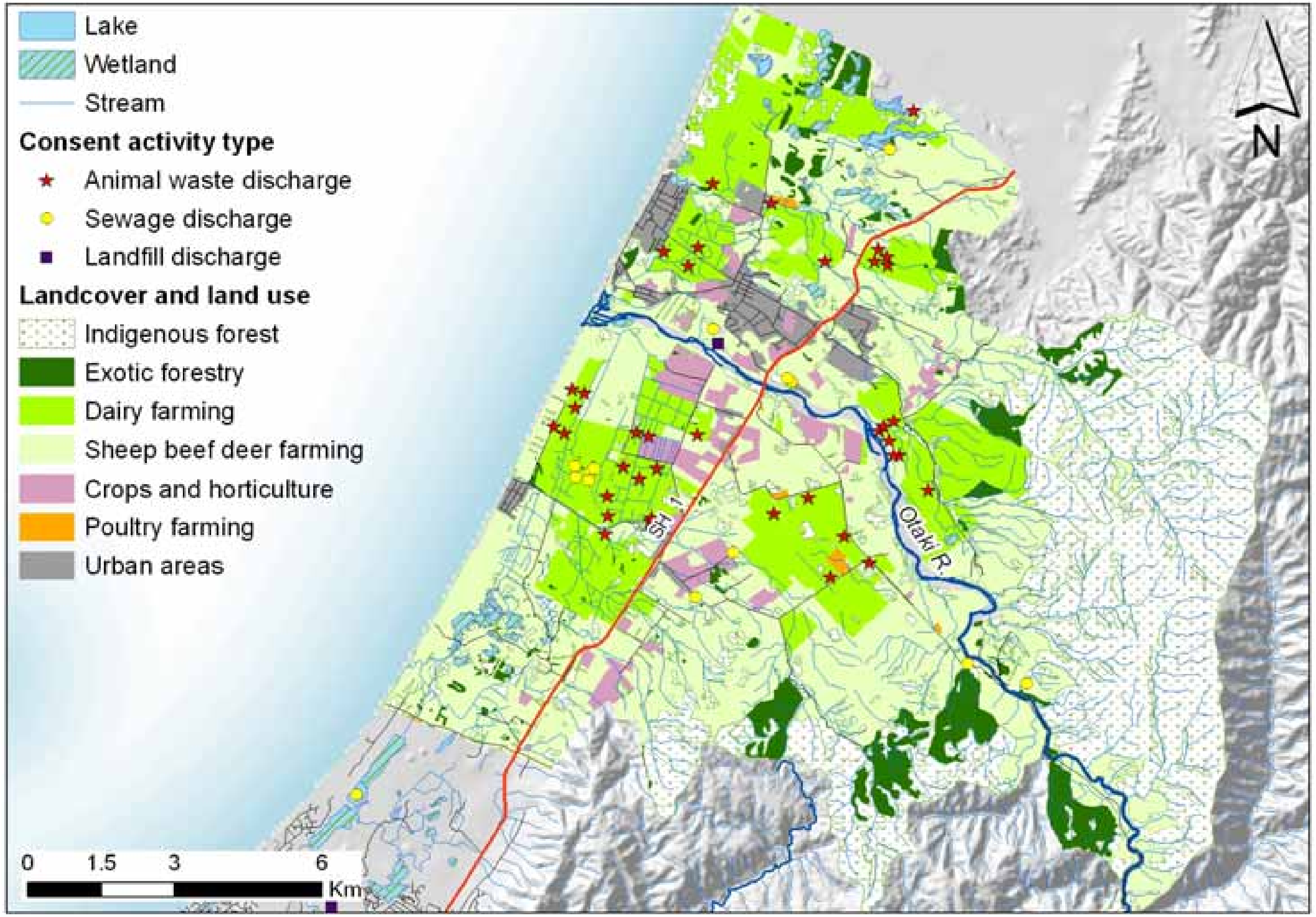

Figure 3.1: Land cover and land use over the Otaki, Hautere, Waitohu and Coastal groundwater zones and around the river and stream headwaters. Consented land discharges indicate where sources of contaminants may infiltrate into groundwater.
(Source: Agribase Assurequality 2001 & Land Cover Database MfE 2001)

3.2 Former land use

Kampman & Caldwell (1985) and Wilson (2003) both make note of the significant land use changes that have occurred on the Kapiti Coast. Prior to 1960 much of the land on the Kapiti Coast was used for dairy farming and this continues to be one of the prominent land uses today. Early dairy farms used water races to meet their water demands, however by the end of the 1970s most farms were reliant on bore water.

Land began to be used for market gardening around the 1960s and in the 1980s there was rapid development of land into horticulture blocks of kiwifruit. The area of land planted in kiwifruit orchards grew from 4 hectares in 1979 to 350 hectares in 1984 (Cussins 1994). During the 1980s there was also an increase in the number of bores drilled on the Kapiti Coast as dependence on bore water for irrigation grew rapidly.

Recently there has been a conversion of kiwifruit orchards into other types of orchards, market gardens or dairy pasture. The land area used for dairy farming has increased with larger herds and more demand for water. There has also been an increase in lifestyle blocks and expansion of coastal settlements, which generally rely on shallow bore water to supplement public supply and have on-site wastewater systems to treat and dispose of wastewater from individual dwellings.

3.3 Water abstraction

Water abstraction from groundwater, rivers and streams can reduce the amount of water available for aquatic ecosystems, recreational activities and other potential uses and increase the risk of saline intrusion in coastal aquifers. Pressure on water resources generally occurs during dry periods (summer) when groundwater levels and river flows are low. Over-abstraction during these times can place stress on water resources and water-dependent ecosystems.

Resource consent has been required for bore or well construction in the Wellington region since 2002. However, if the groundwater take is less than 20,000 L/day then the Regional Freshwater Plan states the user does not require a consent to take groundwater (subject to a number of conditions) (WRC 1999b).

There are 75 consented water takes within the investigation area (Figure 3.2), with the majority of these takes from groundwater abstraction (only nine surface water takes). However, there are over 500 bores which are less than 15m deep (considered to be within the shallow aquifer). It is believed that many of theses bore are used to supplement public supply either during water restrictions (summer months) or for domestic use (mix of potable, toilet flushing, washing machines) and garden irrigation (Jones & Baker 2005). Currently groundwater abstraction from these bores is not monitored or regulated and therefore the quantity of groundwater used is unknown. The cumulative impact of pumping groundwater from these shallow bores especially in areas where the number of bores is highly concentrated (Te Horo Beach, Peka Peka Road and Te Hapua Road) is also relatively unknown (Jones & Baker 2005).

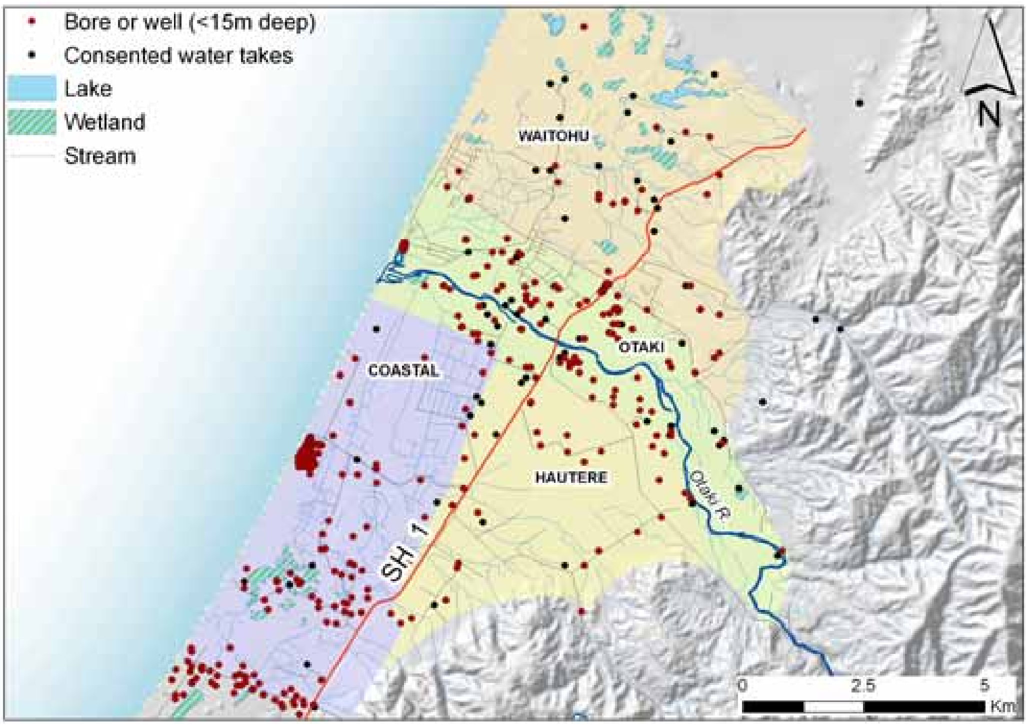

Figure 3.2: The locations of consented water takes compared with the number of shallow bores on the Kapiti Coast. It is thought that most shallow bores are used to supplement public supply or for garden irrigation.

Other studies have focused on the risk from saline intrusion due to abstraction from a large number of bores in a relatively small area. Saline intrusion can be difficult to rectify and makes water supplies unsuitable for potable or irrigation supply without expensive treatment. A study of Te Horo Beach settlement suggests that saline intrusion has occurred at the settlement due to over-abstraction of the shallow aquifer and salt water may have intruded 10 metres inland of its natural position (Wilson 2003).

3.4 Population growth

Between 2001 and 2006 the Kapiti Coast District experienced the second largest population growth in the Wellington region after Wellington City (KCDC 2007). It is expected that the total population for the district will be around 50,000 at the 2011 census, an increase from 46,200 in 2006 (KCDC 2007). Much of the growth is seen in the townships of Waikanae, Paraparaumu and Raumati, which make up 77% of the total population for the Kapiti Coast District. Rural areas make up 8% of the total population and statistics show considerable growth in the rural areas from Te Horo south (KCDC 2007).

The expected increase in the rural population may see a rise in the number of individual on-site wastewater treatment systems installed on the Kapiti Coast and thus increase the amount of wastewater and nutrients being discharged to land.

4. Kapiti Coast groundwater quality – previous studies[1]

Groundwater quality on the Kapiti Coast has been investigated in a number studies. The earliest investigations were conducted by Kampman & Caldwall (1985) for the Manawatu Catchment and Regional Water Board. Fifteen bores were sampled on a six-monthly basis from 1982 to 1985. A further 56 bores were sampled on a single occasion in October 1982 to increase coverage over the Waitohu, Otaki, Te Horo and Coastal areas. Over the three years of monitoring nitrate concentrations ranged from 3 mg/L to 13 mg/L with many results close to the current DWSNZ (2005) maximum acceptable value (MAV) of 11.3 mg/L. The shallow aquifers in the central Hautere and upper Coastal groundwater zones were most affected, while concentrations recorded in deeper aquifers were generally below 3 mg/L.

In 1994, a large-scale study into the surface water and groundwater hydrology of the Kapiti Coast was conducted (WRC 1994). Nitrate concentrations in a number of bores sampled at the time were above the current DWSNZ (2005) MAV in the Otaki and Hautere groundwater zones. Sources of nitrate were attributed to local farming and horticultural practices. Faecal indicator bacteria were also detected in the shallow aquifers of the Coastal, Hautere and Otaki groundwater zones.

Baseline monitoring undertaken between 1994 and 1996 indicated that groundwater quality on the Kapiti Coast was highly variable. Two reports released over two consecutive years (WRC 1995, WRC 1996) commented on the prevalence of elevated nitrate concentrations in shallow aquifers. Groundwater sampled from a number of bores in the Waitohu, Otaki and Hautere groundwater zones had nitrate concentrations which were above or close to the current DWSNZ (2005) MAV. A maximum nitrate concentration of 29 mg/L was recorded in bore S25/5398 (Otaki groundwater zone) and sample results from bores S25/5256 and S25/5322 (Hautere and Waitohu groundwater zones respectively) were consistently above the MAV. Many of the bores sampled were used for potable supply.

The findings of the two baseline monitoring reports led to further investigation by Hughes (1997) into the magnitude and extent of groundwater nitrate contamination on the Kapiti Coast. Sampling was conducted in early December 1996, with a total of 64 samples collected, including samples from the Otaki River, Mangaone Stream and one spring. Results indicated that the Hautere groundwater zone was the most affected by nitrate contamination. A number of samples from bores in the area between State Highway 1, Addington Road and Te Waka Road recorded nitrate concentrations above the current DWSNZ (2005) MAV (Figure 4.1). Nitrate concentrations recorded in the Hautere groundwater zone had increased 20 to 40% in the 14 years between 1982 and 1996 (Hughes 1997). Further analysis shows of the 34 bores sampled in the Hautere area, 12 had nitrate concentrations above the current DWSNZ (2005) MAV while 10 had concentrations between 7-11.3 mg/L (Hughes 1998).

[1] The summary provided here focuses principally on nitrate concentrations as this was the major contaminant of interest in the 2008 groundwater quality investigation.

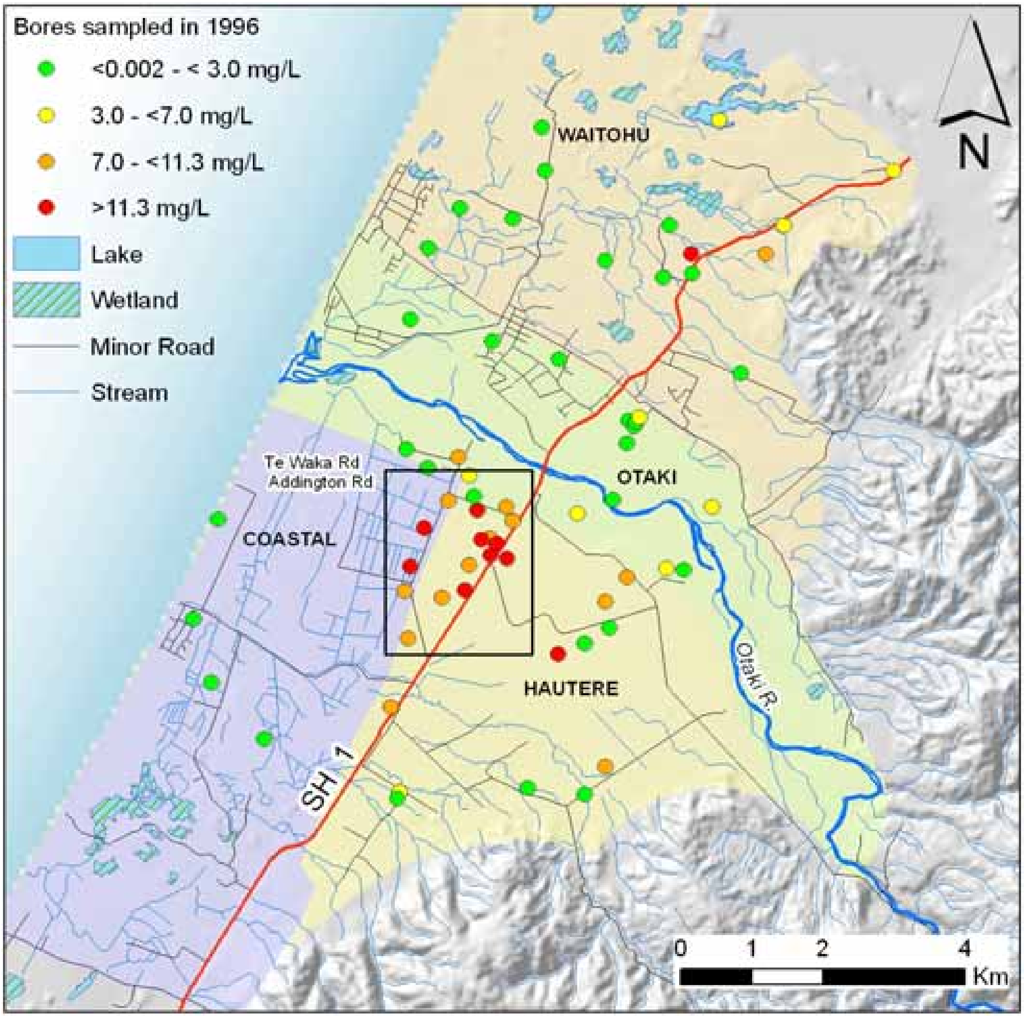

Figure 4.1: Nitrate-nitrogen concentrations recorded in northern Kapiti Coast bores sampled during November 1996

In a smaller investigation of the Te Horo Beach settlement, Hughes (1998) investigated complaints lodged with the regional council by local residents. Residents claimed that groundwater appeared to be affected by saline intrusion and aesthetic problems such as poor taste, odour and high turbidity. Sampling of 20 shallow domestic bores was carried out in January 1998 in an effort to capture the effects of peak occupancy at the beach settlement. The nitrate concentration in one bore sample was highly elevated (8.6 mg/L) but generally the concentrations recorded in other bore samples were below 3 mg/L. Microbial analysis confirmed the presence of faecal bacteria in only one of the 20 bores sampled, suggesting that there was little contamination from septic tanks. However, dye tracing tests conducted by the Kapiti Coast District Council in 1993 and the Hutt Valley Public Health Service in 1997 had showed that wastewater from septic tanks was able to move quickly into the bore water supplies of neighbouring properties. This raised concern that pathogenic microbes could still migrate via the groundwater into bores. Therefore it was recommended that Te Horo residents do not use the groundwater for potable supply (Hughes 1998).

5. Groundwater quality investigation 2008 – sampling sites, methods and results

This section provides an overview of the 2008 groundwater investigation area, sampling sites and analytical methods. The sampling results are also presented.

5.1 Investigation area

The 2008 targeted investigation focused on the Hautere, Coastal, Otaki and Waitohu groundwater zones on the northern Kapiti Coast. The investigation incorporated two key land-uses with the potential to impact on groundwater quality: intensive agricultural/horticultural land use (Hautere and Waitohu plains) and coastal residential expansion incorporating on-site wastewater discharges (Te Horo Beach) (Figure 5.1).

The four groundwater zones were selected based on monitoring results from 10 bores located on the Kapiti Coast which are sampled quarterly in Greater Wellington's Groundwater State of Environment (GWSoE) monitoring programme. Nitrate concentrations recorded in some of these bores are elevated and, in some cases, concentrations have exceeded the DWSNZ (2005) MAV.

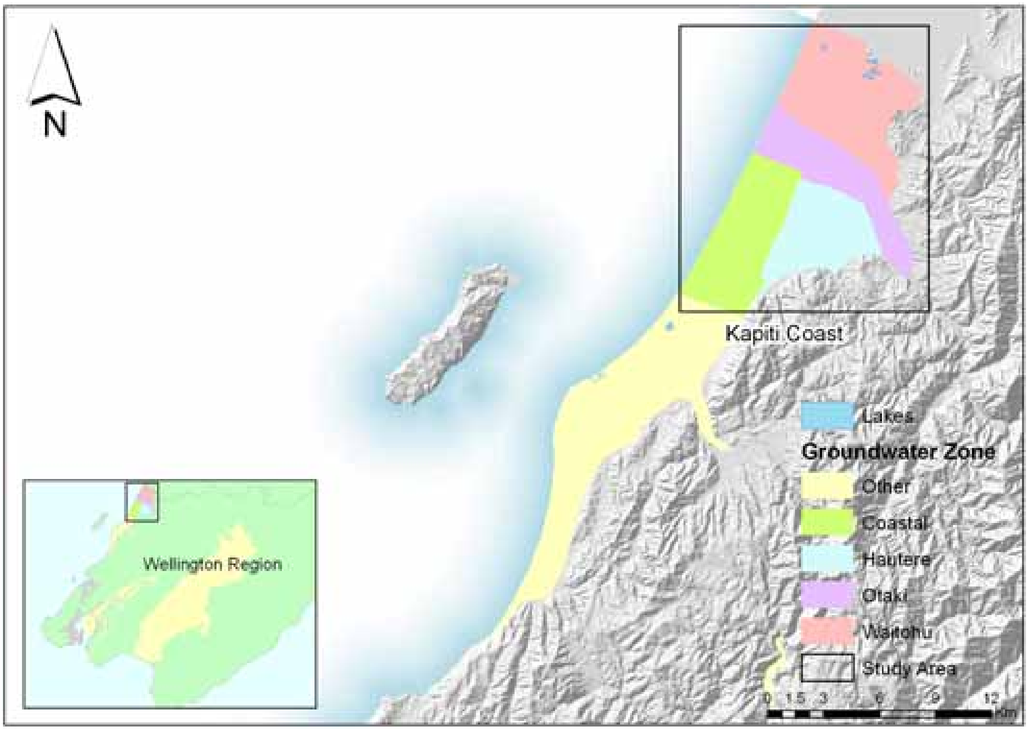

Figure 5.1: Location of the Kapiti Coast investigation area selected for targeted groundwater quality sampling during November and December 2008

5.2 Bore selection

A number of the existing GWSoE bores and bores sampled in previous investigations were selected again for the 2008 investigation. Substantial effort was made to relocate and sample the bores that were sampled in 1996 (Hughes

1997). However, a number of bores could not be located or sampled due to changes of bore/property ownership. In some cases, bores no longer worked or existed, original GIS co-ordinates were inaccurate or Greater Wellington was not granted access to the bore. These factors eliminated a large number of bores from the 2008 sample selection and of the 62 bores sampled in 1996, only 15 were re-sampled in 2008.

From 24 November to 2 December 2008, a total of 31 bores were sampled in the targeted investigation area (see Appendix 2 for details)[2]. Of these, 10 were GWSoE bores, four of which were originally sampled in 1996.

5.3 Sampling methods and sample analysis

Groundwater samples were collected by trained Greater Wellington staff using nationally accepted protocols (Ministry for the Environment 2006). This involved purging the bore for a predetermined amount of time to remove any standing water and monitoring the pumped water continuously for parameter stabilisation. These practices were employed to make sure that the water sampled was representative of the aquifer. Care was also taken to ensure that the water sampled was not contaminated by other sources through mishandling of sampling equipment, containers or by other water sources.

Water samples were stored on ice upon collection and transported to Greater Wellington's contracted laboratory (Hill Laboratories, Hamilton) for analysis within 24 hours of sampling. Methods of analysis used by Hill Laboratories are provided in Appendix 3. Field measurements (temperature, conductivity, pH and dissolved oxygen) were taken using a YSI-556 or WTW350i field meter and flow cell. Field meters were calibrated on the day of sampling. Water samples were tested for one or more dissolved nutrients (nitrate, nitrite, total Kjeldahl nitrogen, total nitrogen and total oxidised nitrogen, ammonia and DRP) as well as faecal indicator bacteria (*E. coli)*.

5.4 Data interpretation, analysis and presentation

Groundwater sample results were compared against the DWSNZ (2005). These standards apply to water used for human consumption and set a maximum acceptable value (MAV) of:

- 50 mg/L nitrate (NO_3) or an equivalent of 11.3 mg/L as nitrate-nitrogen (NO_3-N);
- 0.2 mg/L for nitrite (NO_2)[3] or an equivalent of 0.06 mg/L as nitrite-nitrogen (NO_2-N); and
- <1 cfu/100 mL for *E. coli* and faecal coliforms.

There are no MAVs for ammonia or DRP.

Groundwater nitrate concentrations were also evaluated in terms of likely human influence. Groundwater in New Zealand rarely demonstrates concentrations above 1 mg/L naturally (Close et al. 2001), therefore a threshold

2 KCDC provided the results for "KCDC Bore 3" sampled on 7 December 2008.

3 Provisional MAV for long-term exposure.

of 3 mg/L has been adopted as a means of defining nitrate contamination from anthropogenic sources (Close et al. 2001). This threshold follows the findings of a US study of nitrates (Madison & Brunett 1985) that concluded concentrations of nitrate in groundwater above 3 mg/L were due to human influence. Therefore, in this report, reference to 'elevated' nitrate concentrations indicates the concentrations are above 3 mg/L. The term 'highly elevated' refers to nitrate concentrations which range between 7-11.3 mg/L. This term is used only as a means of classification to indicate where nitrate concentrations are above the elevated status but below the DWSNZ (2005) MAV.

5.5 Temporal trend analysis

As the 2008 investigation was based on one-off sampling, temporal changes in groundwater quality must be inferred using data from nearby GWSoE monitoring bores. GWSoE monitoring bores are sampled at three-monthly intervals, with data records going as far back as the early 1990s for some bores.

Trend analysis was conducted on nitrate data for each of the 10 GWSoE bores using the NIWA Time Trends software (Version 3 2009). The start of the monitoring period varies between sites with monitoring commencing from 1993 to 1999. Data with values less than the laboratory's analytical detection limit were assigned a value of one half of the most conservative detection limit[4].

Seasonal-Kendall analysis for both two and four seasons using Kruskal-Wallis and Mann-Whitney tests showed no statistical significance between seasons except at one site, R25/5165. Therefore a Mann-Kendall test with a confidence level of 95% was used to identify statistically significant trends (i.e., the probability of the observed trend is unlikely to be due to chance); the accompanying Sen's slope estimator was used to determine the magnitude and direction of the trend for each site.

5.6 Sampling results

Results of groundwater sampling conducted during November and December 2008 are summarised in Table 5.1 and are provided in full in Appendix 2.

Nitrate concentrations ranged from less than the laboratory's detection limit (0.002 mg/L) to 11 mg/L, with overall mean and median concentrations of 3 and 1.9 mg/L respectively. The highest nitrate concentration was recorded in bore S25/5322 (11 mg/L) located in the Waitohu groundwater zone. No sample results exceeded the DWSNZ (2005) MAV of 11.3 mg/L.

[4] Any nitrate values less than half of the most conservative detection limit were treated as "tied" values and were also replaced by one half of the most conservative detection limit. This is in line with practices outline in Helsel & Hirsh (2002).

Table 5.1: Summary statistics for one-off groundwater samples collected from 31 bores in the Kapiti investigation area during November/December 2008

Variable	Minimum	Mean	Median	Maximum	DWSNZ (2005) MAV
E. coli (cfu/100mL)	<1	<1	<1	2	<1
Nitrite Nitrogen (mg/L)	0.001	0.003	0.001	0.039	0.06
Nitrate Nitrogen (mg/L)	0.001	3.0	1.9	11	11.3
Total Kjeldahl Nitrogen (mg/L)	0.05	0.187	0.05	1.2	-
Ammoniacal Nitrogen (mg/L)	0.015	0.10	0.05	0.81	-
Total Nitrogen (mg/L)	0.055	3.26	1.95	10	-
Dissolved Reactive Phosphorus (mg/L)	0.0056	0.099	0.022	0.71	-
Field pH	4.85	6.26	6.16	7.88	7.0–8.5
Field Conductivity (µS/cm)	80	272	233	1,291	-

Samples from six bores (R25/5244, S25/5365, S25/5256, S25/5252, S25/5322, R25/5177) had highly elevated (>7 mg/L) nitrate concentrations; three of these bores (R25/5244, S25/5365 and S25/5256) are located in the Hautere groundwater zone in a horticultural area. Bore S25/5252 is located approximately 50 metres downgradient of an old effluent pond on a dairy farm in the Hautere groundwater zone, while bore S25/5322 is located in the Waitohu groundwater zone in an orchard and bore R25/5177 is located in the Coastal groundwater zone downgradient of a horticulture area within an area of dairy farming (Figure 5.2).

Samples from four bores (S25/5375, S25/5427, R25/5257 and R25/5190) recorded elevated concentrations of nitrate (3-7 mg/L). Bores S25/5375 and S25/5427 are located in the Waitohu groundwater zone, with the latter bore being downgradient of a dairy farm. In contrast, bore R25/5257 is located in the Otaki groundwater zone downgradient of a horticultural area and bore R25/5190 is located within an area of sheep and beef farming in the Coastal groundwater zone. The remaining 21 borewater samples had nitrate concentrations below 3 mg/L (Figure 5.2).

An assessment of nitrate concentration against bore depth indicates that elevated to highly elevated concentrations of nitrate (3-11.3 mg/L) in the groundwater can be found at depths ranging from 0-30 metres (Figure 5.3), particularly in bores greater than 15 metres deep (7 of the 10 bores) located within the Waitohu or Hautere groundwater zones.

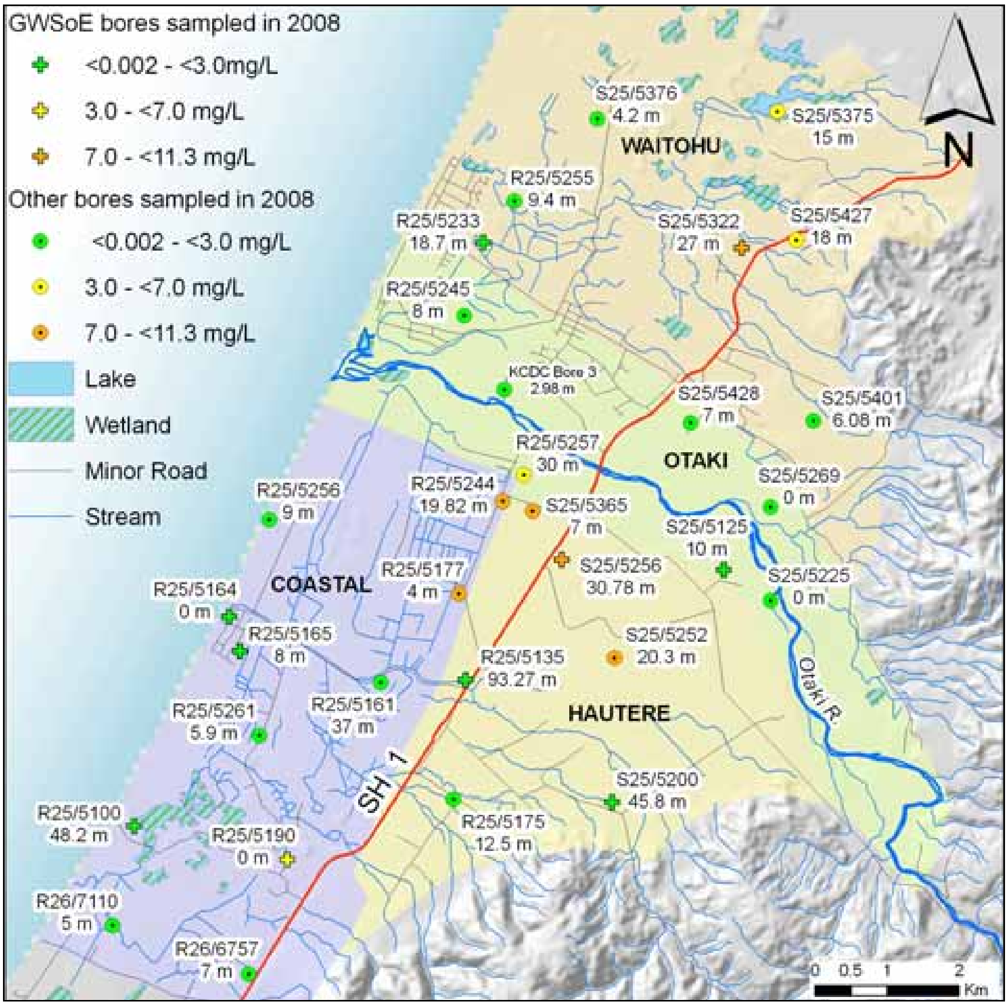

Figure 5.2: Nitrate-nitrogen concentrations recorded in 31 groundwater bores on the northern Kapiti Coast during one-off sampling in November/December 2008. Bore depths are also shown.

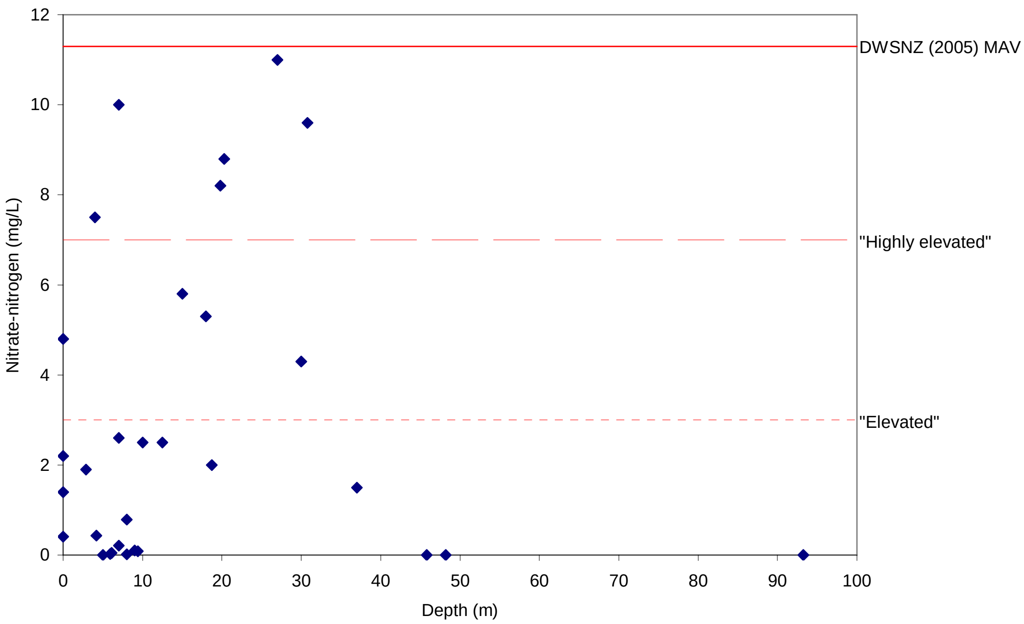

Figure 5.3: Bore depth compared against nitrate-nitrogen concentrations recorded on the northern Kapiti Coast during one-off sampling in November/December 2008

Nitrite concentrations were below the DWSNZ (2005) MAV of 0.06 mg/L in all bores sampled, with concentrations ranging from less than the laboratory's detection limit (0.002 mg/L) to 0.039 mg/L. The highest nitrite concentration was recorded in bore R25/5256, located in the Otaki groundwater zone approximately 145m from the sea.

Concentrations of TKN ranged from less than the laboratory's detection limit (0.1 mg/L) to 1.2 mg/L. Mean and median concentrations of TKN were 0.187 mg/L and <0.1 mg/L respectively. The highest TKN concentration was recorded in bore R26/7110 in the Coastal groundwater zone.

Total nitrogen concentrations ranged from 0.055 mg/L to 10 mg/L[5]. Mean and median concentrations of total nitrogen were 3.26 mg/L and 1.95 mg/L respectively. Total nitrogen concentrations were highest in bores S25/5365, S25/5252, R25/5244 and R25/5177. These bores are located in the Hautere and Coastal groundwater zones in areas where nitrate concentrations in the groundwater are also high.

DRP concentrations ranged from 0.0056 to 0.71 mg/L, with overall mean and median concentrations of 0.099 mg/L and 0.022 mg/L respectively. There is no DWSNZ (2005) MAV for DRP but samples from seven bores recorded DRP concentrations above 0.1 mg/L. These included bores R25/5164, R25/5261, R25/5165, R25/5100 and R26/7110 in the Coastal groundwater zone and bores S25/5200 and R25/5135 in the Hautere groundwater zone. DRP concentrations above 0.1 mg/L appear to be prominent in the Coastal groundwater zone with only two results above this concentration recorded from samples collected in the Hautere groundwater zone. Four of the seven bores with DRP concentrations above 0.1 mg/L are less than 10 metres deep while the remaining three bores are greater than 40 metres deep.

Ammonia concentrations ranged from less than the laboratory's detection limit (0.01 mg/L) to 0.81 mg/L, with overall mean and median concentrations of 0.08 mg/L and <0.01 mg/L respectively. No ammonia concentrations exceeded the DWSNZ (2005) guideline value of 1.5 mg/L for odour and taste thresholds.

Counts of *E. coli* in all borewater samples were below the DWSNZ (2005) MAV of <1 cfu/100mL except in bores S25/5365 and S25/5401 which had *E. coli* counts of 1 cfu/100mL and 2 cfu/100mL respectively. Both bores are six to seven metres deep, with bore S25/5401 located approximately 150 metres from the Waitohu Stream.

5.7 Temporal trends in nitrate concentrations

The results of temporal trend analysis using the Mann-Kendall test are summarised in Table 5.2 and Figures 5.4 and 5.5. Data used for trend analysis are listed in Appendix 4 and the results of the Mann-Kendall test for each site are given in Appendix 5. Of the 10 sets of nitrate data examined, three showed a statistically significant decrease ($p<0.05$) in nitrate concentrations and one

[5] Samples from GWSoE bores were not tested for total nitrogen. The highest nitrate concentration (11 mg/L) was recorded in a GWSoE bore, while the highest nitrate and total nitrogen concentration recorded in a non-GWSoE bore was 10 mg/L.

showed a statistically significant increase ($p<0.05$) (Figure 5.4). Nitrate data from one further site showed a decreasing trend, although it was only statistically significant to $p<0.1$.

Daughney & Reeves (2006) defined a rate of change greater than ± 0.1 mg/L/yr as being due to human activity rather than natural fluctuations in groundwater chemistry. Therefore, if a statistically significant trend is detected at a site with a rate of change greater than ± 0.1 mg/L/yr, this indicates that the trend is also environmentally significant.

The relative rate of change is calculated by dividing the rate of change evident over the report period (calculated by the Sen's slope estimator) by the median value for the data set. Daughney[6] (pers. comm. 2009) suggests that a relative rate of change greater than 5% is probably due to human activity and is likely to also be environmentally significant.

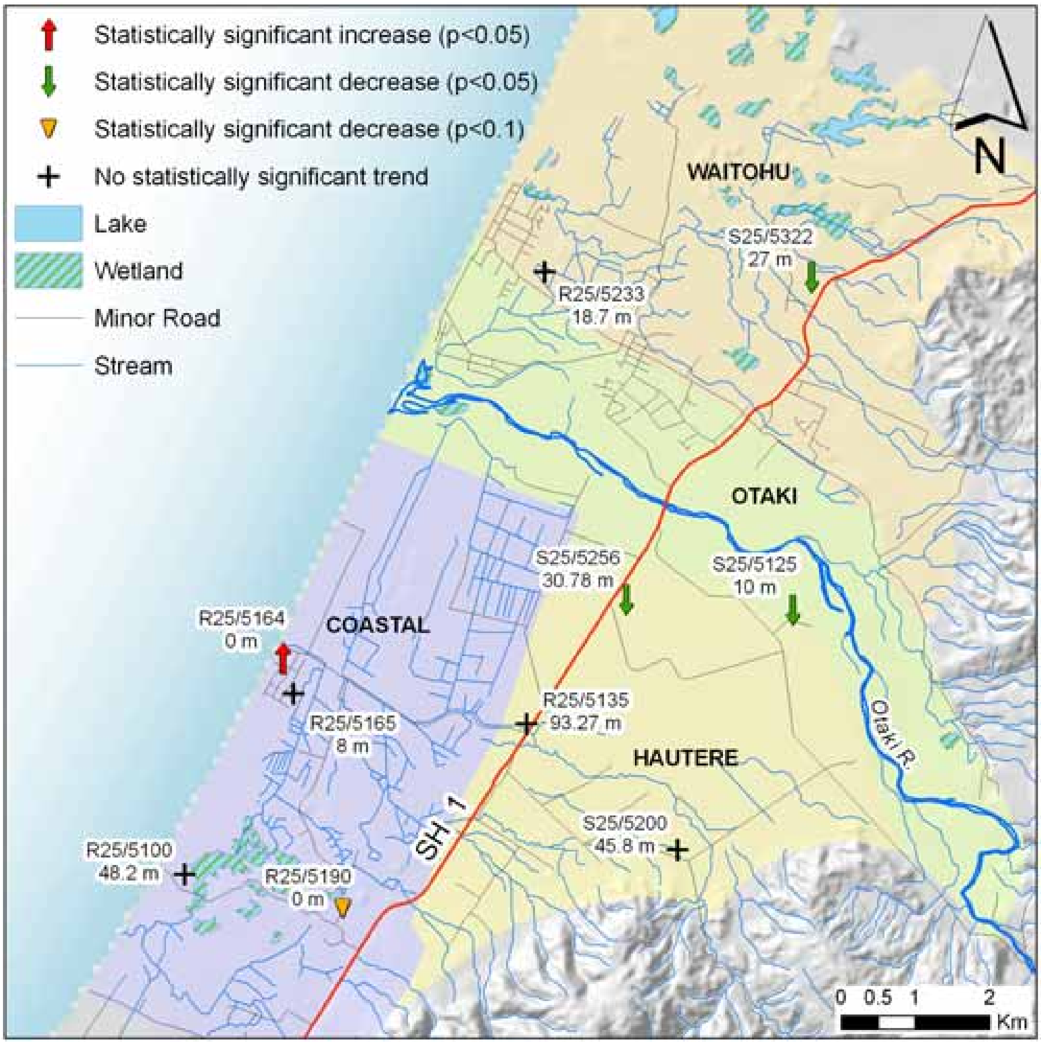

Figure 5.4: Temporal trends in nitrate-nitrogen concentrations in GWSoE bores sampled quarterly over 1993 to 2008

[6] Dr Chris Daughney, GNS Science

From Table 5.2 and Figure 5.5 it can be seen that:

- Statistically significant (*p*<0.001–*p*=0.01) and environmentally significant (rate of change > ±0.1mg/L/yr) decreasing trends in nitrate concentrations were detected in bores S25/5256, S25/5125 and S25/5322, with the rate of decrease in nitrate concentrations being -0.28, -0.29 and -0.31 mg/L/yr respectively.

- Prior to 2000-2003, nitrate concentrations in these three bores were initially above or very close to the DWSNZ (2005) MAV of 11.3 mg/L. Nitrate concentrations are now below the MAV threshold. Nitrate concentrations in bores S25/5256 and S25/5322 are still in the "highly elevated" range.

- Bores S25/5256, S25/5125 and S25/5322 are located within horticultural areas and are used for irrigation.

- A significant (*p*<0.1) and environmentally significant decreasing trend (rate of change > ±0.1mg/L/yr) in nitrate concentration was also detected in bore R25/5190 (-0.35 mg/L/yr). This bore has only been monitored regularly since December 2003 and is located amongst land used for agriculture.

- A statistically significant (*p*<0.001) and environmentally significant (relative rate of change >5%) increasing trend in nitrate concentration was detected in bore R25/5164 (0.04 mg/L/yr). However, up until December 2004 nitrate concentrations were stable and showed no trend. Since December 2004, concentrations have shown a steady increase although nitrate concentrations remain below the elevated threshold (3 mg/L).

Despite the overall decreasing trend in nitrate concentrations in bore S25/5125, concentrations appear to vary greatly about the trend line compared to results recorded in bores S25/5322 and S25/5256 (Figure 5.5). Bore S25/5125 is a shallow (10 m) bore located in the Otaki groundwater zone, which is predominantly recharged by the Otaki River. To investigate the variability further, a comparison was made between nitrate concentrations and average river flow in the 28 days prior to sampling. In general, higher concentrations of nitrate in bore S25/5125 tend to coincide with higher flows in the month prior to sampling, and when there were low flows prior to sampling the nitrate concentrations tended to be lower (Figure 5.6). However, it is apparent from Figure 5.6 that nitrate concentrations in bore S25/5125 are not completely correlated with river flow conditions, and there may still be an underlying trend of decreasing nitrate concentrations regardless of the recharge conditions prior to sampling.

Table 5.2: Summary of temporal trend analysis performed on nitrate data from 10 GWSoE sites (sampled quarterly from 1993 to 2009) using the Mann-Kendall test and Sen's slope estimator

GWSoE Site	S25/5322	R25/5233	S25/5125	S25/5256	S25/5200	R25/5135	R25/5190	R25/5165	R25/5164	R25/5100
Bore depth (m)	27	18.7	10	30.78	45.8	9.327	Unknown	8	Unknown**	48.2
Bore use	Irrigation	Stock	Irrigation	Irrigation	Irrigation	Irrigation	Potable and stock	Domestic	Domestic	Irrigation
Groundwater zone	Waitohu	Waitohu	Otaki	Hautere	Hautere	Hautere	Coastal	Coastal	Coastal	Coastal
Trend period	May 1993 – March 2009	June 1996 – March 2009	March 1996 – March 2009	May 1993 – March 2009	May 1993 – March 2009	May 1993 – March 2009	June 1999 – March 2009	March 1998 – March 2009	Sept 1997 – March 2009	Sep 1993 – March 2009
n	56	51	42	49	41	45	24	43	44	45
Minimum	9.3	0.33	0.824	8.8	0.005	0.005	3	0.005	0.005	0.005
Mean	11.9	1.6	4.1	11.2	0.01	0.01	5.8	0.784	0.2	0.009
Median	12.2	1.6	3.6	10.9	0.005	0.005	5.4	0.044	0.03	0.005
Maximum	15	2.9	10.8	15	0.08	0.086	12.6	6.1	2.4	0.03
Median annual Sen slope	-0.31	0.04	-0.29	-0.28	0	0	-0.35	-0.01	0.04	0
p-value	<0.001	0.316	0.010	<0.001	0.389	0.656	0.070	0.129	<0.001	0.691
Trend detected (Y/N)	Y	N	Y	Y	N	N	N	N	Y	N
Trend type (increase or decrease)	Decrease	–	Decrease	Decrease	–	–	–	–	Increase	–
Environmentally significant trend (Y/N) (Rate of change greater than ±0.1 mg/L/yr)	Y	–	Y	Y	–	–	–	–	N	–
Relative rate of change*	2.54%	–	8.05%	2.56%	–	–	–	–	133%	–
Environmentally significant trend (Y/N) (Relative rate of change greater than 5%)	N	–	Y	N	–	–	–	–	Y	–

* Percent rate of change only calculated for sites where a statistically significant trend has been detected

** Assumed to be a shallow sand trap bore that supplies water for domestic use (although not potable use)

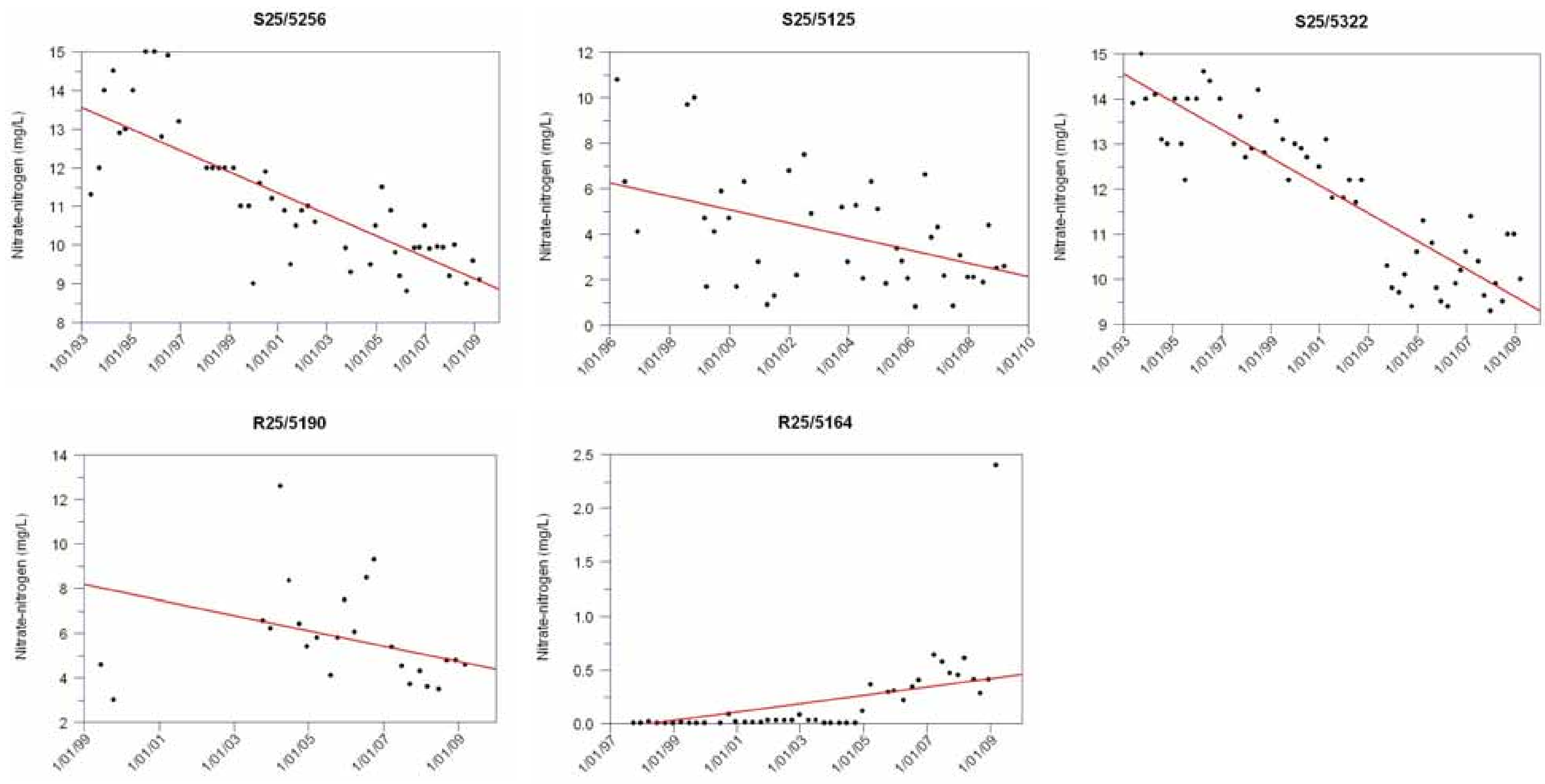

Figure 5.5: Nitrate-nitrogen concentrations recorded in bores S25/5256, S25/5125, S25/5322, R25/5190 and R25/5164 from 1993 to 2009. The red line indicates the Mann-Kendall slope trend line. Statistically significant decreases (p<0.001–p=0.01) ranging from -0.28 to -0.31 mg/L/yr were recorded in bores 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). A statistically significant increase (p<0.001) was also recorded in bore R25/5164 (0.04 mg/L/yr).

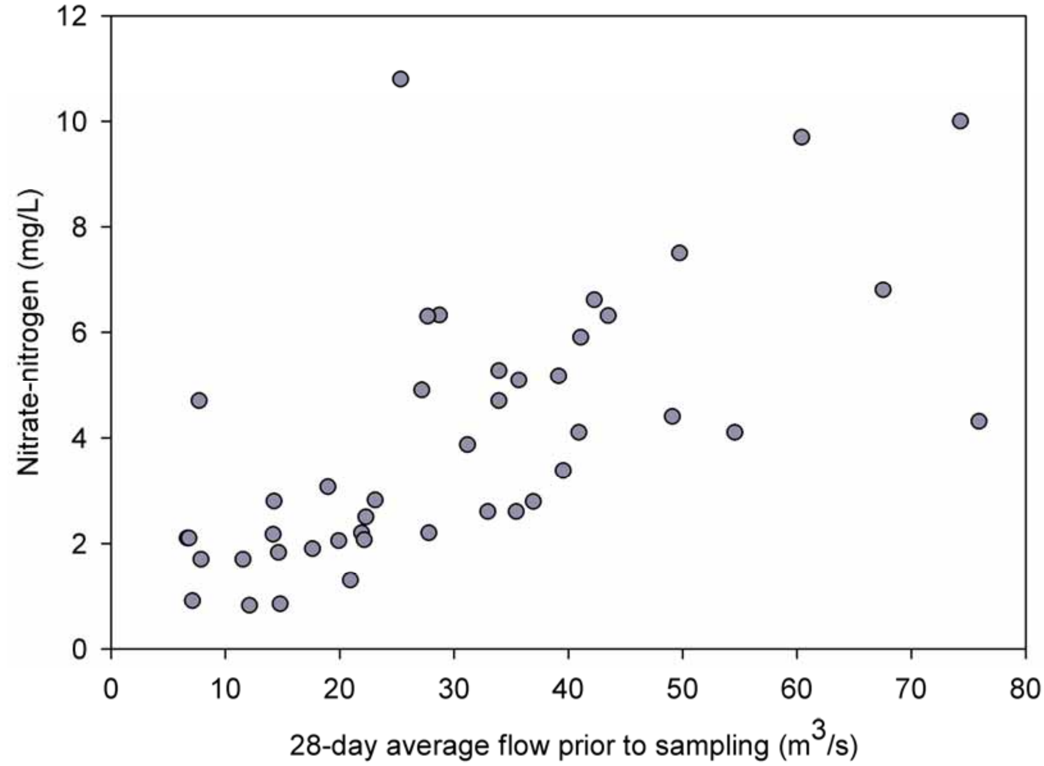

Figure 5.6: Nitrate-nitrogen concentrations recorded in bore S25/5125 (Otaki groundwater zone), 1996-2009, compared to average flow in the Otaki River for the 28 days prior to sampling

6. Discussion

Sampling on the northern Kapiti Coast during November and December 2008 has indicated that nitrate concentrations in the groundwater are low to highly elevated. While no individual sample results exceeded the DWSNZ (2005) MAV for nitrate, samples from 10 bores had elevated concentrations of nitrate (3–11.3 mg/L). The majority of the elevated results came from bores located in the Waitohu and Hautere groundwater zones and within (or downgradient of) areas of land that are and/or have historically been used for intensive agriculture or horticulture. In some cases these bores are also downgradient of animal effluent and sewage discharges to land (Figure 6.1). This suggests that nitrate contamination in the groundwater may be arising are from land management practices and discharges to land. However, further tests are required to confirm the source(s) of nitrate. Analysis of nitrogen isotopes could assist with this and age-dating tests could help determine when nitrogen entered the groundwater (thus helping to distinguish between past or present land use as the source of nitrogen contamination).

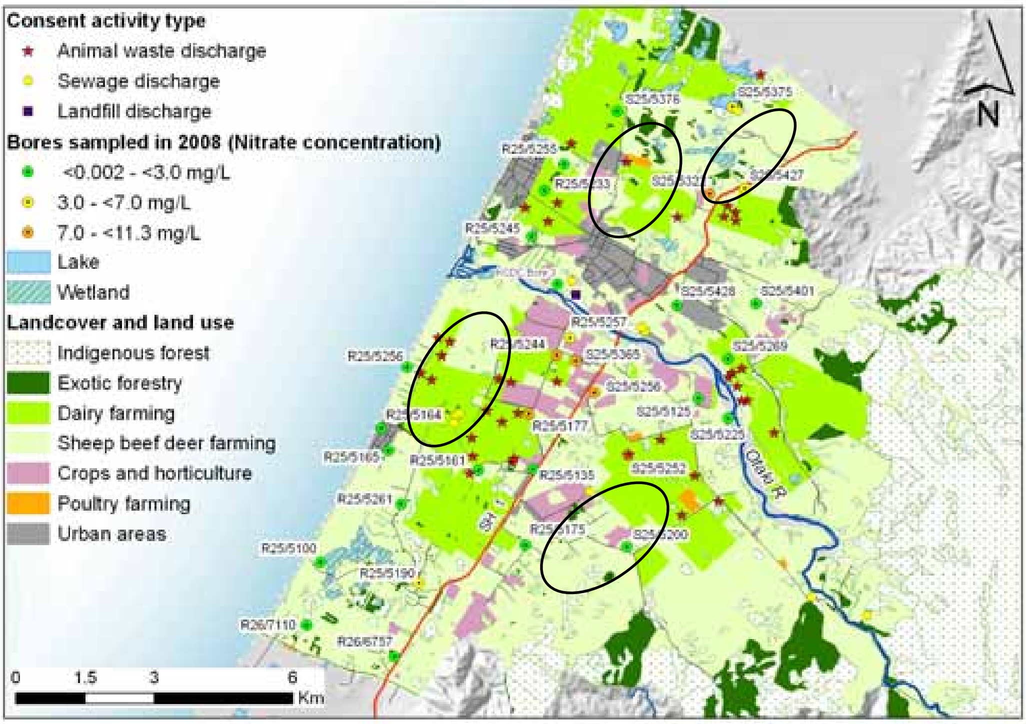

Figure 6.1: Nitrate concentrations recorded in northern Kapiti Coast monitoring bores during November/December 2008. The land cover and land use over the Waitohu, Otaki, Hautere and Coastal groundwater zones and consented discharges to land indicate where sources of contaminants may infiltrate into the groundwater. Ovals indicate where more monitoring is required.

(Source: Agribase Assurequality 2001 and Land cover Database MfE 2001)

Elevated concentrations of nitrate were found at depths ranging from 0-30 metres below the ground surface. Many of the bores with highly elevated nitrate concentrations are located within aquifers which are unconfined or semi-confined and where there is a downward pressure gradient. It is likely that nitrate is able to move depths of 30 metres with recharge through leakage from shallow aquifers to deeper aquifers, especially in the Waitohu and Hautere groundwater zones (refer to sections 2.3.1 and 2.3.3).

Nitrate concentrations recorded in water samples from bores in the Otaki and Coastal groundwater zones in late 2008 were generally low (<3 mg/L). Low nitrate concentrations in the Coastal groundwater zone could be due to less intensive land use practices. However, this is difficult to verify as groundwater quality sampling in this zone has been sparse to date.

Piezometric surveying suggests that elevated nitrate concentrations detected in samples taken in 1996 and 2008 may be migrating with groundwater flow away from the sampling sites. The ovals in Figure 6.1 indicate where more monitoring of the shallow groundwater is required in the upper Hautere, mid-Coastal and mid-Waitohu groundwater zones to determine if concentrations of nitrate are present in the groundwater in these areas.

The possibility that groundwater with highly elevated nitrate concentrations is migrating towards ecologically sensitive environments such as streams, lakes and wetland complexes (e.g., Te Hapua and Waitohu wetlands) is of concern. The addition of nutrients to these systems could cause nitrification/eutrophication and degrade the water quality in these environments. For example, recent monitoring in Lake Waitawa (Waitohu) has revealed blooms of potentially toxic cyanobacteria (blue-green algae). These algal blooms are most likely fuelled by elevated concentrations of nutrients (Perrie[7], pers. comm. 2009). A nearby bore (S25/5375), which has elevated nitrate concentrations, is very close to the Forest Lakes wetland complex (Figure 6.1) and it is possible that groundwater in this area is flowing into the lake.

Two of the 31 bores sampled had counts of *E. coli* slightly above the DWSNZ (2005) MAV of <1 cfu/100mL. Both bores (S25/5365 and S25/5401) are located in shallow aquifers. There were no obvious sources of bacteria at the time of sampling. Bore S25/5401 is the only bore used as a potable water supply and the bore owners were notified about the positive *E. coli* count.

Samples from 26 bores were outside the DWSNZ (2005) guideline range for pH (7–8.5). However, most pH values measured in this investigation were typical of New Zealand groundwaters. There did not appear to be a spatial pattern for bores with low pH values. Groundwater on the Kapiti Coast is influenced by the presence of buried organic matter from ancient peat swamps which can make it slightly acidic.

All other variables tested were below the DWSNZ (2005) MAVs or guideline values.

6.1 Comparison of nitrate results recorded in 1996 and in 2008

A comparison of nitrate data collected in 1996 and 2008 suggests that groundwater concentrations of nitrate have decreased in a number of bores, with concentrations now below the DWSNZ (2005) MAV. Temporal trend

[7] Alton Perrie, Environmental Scientist (Surface Water Quality), Greater Wellington

analysis conducted on nitrate data from 10 GWSoE bores supports this assertion (see Section 6.2).

Sampling in 2008 indicated that the same areas identified in 1996 in the Hautere (SH2, Addington Road and Te Waka Road) and Waitohu (western) groundwater zones are still affected by nitrate contamination (Figure 6.2). However, many of the samples analysed in 2008 had lower concentrations of nitrate than concentrations detected in 1996 in these areas. Similarly in the Otaki groundwater zone, nitrate concentrations classed as elevated in 1996 were below the elevated status in 2008. There appears to be no change in nitrate concentrations in the Coastal groundwater zone where nitrate concentrations have generally remained below 3 mg/L (Figure 6.2).

6.2 Temporal trends

Mann-Kendall tests conducted on nitrate data from 10 GWSoE bores detected statistically significant and environmentally significant decreasing trends in three bores (S25/5125, S25/5256 and S25/5322). The rate of decrease in nitrate concentrations ranged from 0.28 mg/L – 0.31 mg/L per year which is greater than would naturally occur in groundwater (Daughney & Reeves 2006). Three bores are located in horticultural areas where land has been in orchards for the last 40 years. In general all three bores historically had nitrate concentrations that were highly elevated or above the DWSNZ (2005) MAV during the 1990s. Recent results in all three bores now show concentrations to be below the DWSNZ (2005) MAV. There is little scientific evidence to explain the observed decreases but anecdotal evidence from horticulturalists on the Kapiti Coast suggest that decreasing nitrate concentrations could be due to:

- a change in land use in the general area, from intensive orchards to less-intensive crops such as olive plantations;
- more efficient fertiliser application and better land management practices (e.g. nutrient budgeting);
- lower fertiliser application rates due to increasing fertiliser costs and greater environmental awareness;
- advances in fertilisers (e.g., development of fertilisers which slowly release their nitrogen content); and
- changes in upgradient land management practices which may be influencing nitrate concentrations in GWSoE monitoring bores.

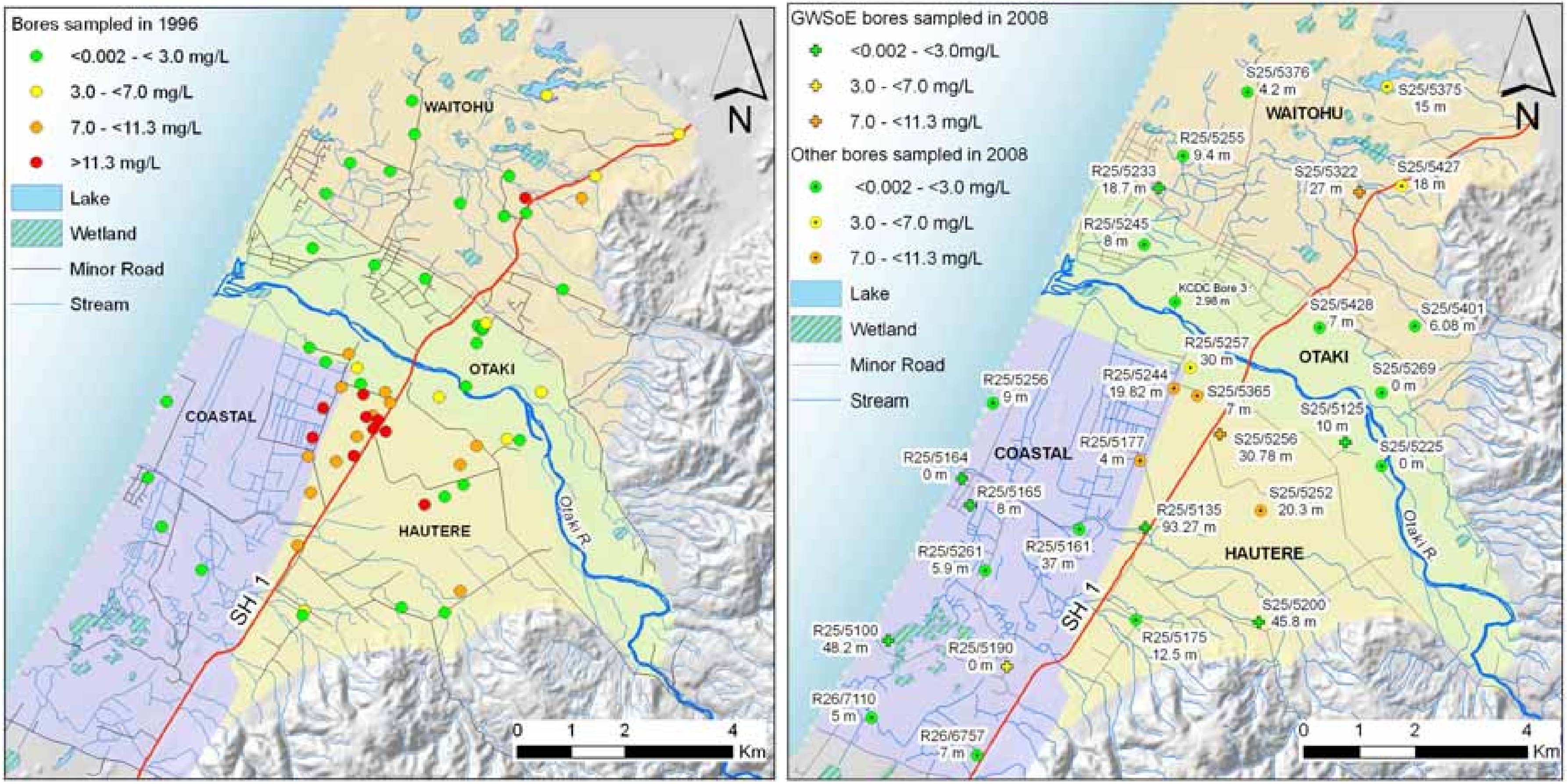

Figure 6.2: Nitrate-nitrogen concentrations recorded in selected bores on the northern Kapiti Coast in 1996 (left) and 2008 (right). In 1996 samples from 10 bores had nitrate-nitrogen concentrations above the DWSNZ (2005) MAV (11.3mg/L), while in 2008 no sample results exceeded the MAV.

The observed decreasing trend in nitrate concentrations in bore S25/5125 in the Otaki groundwater zone may also in part be an artefact of aquifer recharge via the Otaki River (see Section 2.5). For example, nitrate concentrations in this bore tend to be highest when flows in the Otaki River are above average (refer Figure 5.6); when high river flows occur the river water quality is likely to be poorer with high turbidity and nutrient concentrations due to surface runoff.

Trend analysis results for bore R25/5164 (Coastal groundwater zone) detected a statistically significant and environmentally significant increasing trend in groundwater concentration of nitrate, with the increase in concentration occurring steadily from the start of 2005. This bore is located in a beach settlement at Te Horo serviced by on-site wastewater treatment systems which discharge treated wastewater into the shallow aquifer. Residents have long been aware that the groundwater is not safe to drink due to possible contamination of bore water from wastewater systems (see Section 4).

Examination of iron, manganese, ammonia, chloride and sulphate concentrations recorded in groundwater samples from bore R25/5164 over the trend analysis period suggests the position of the saline-freshwater interface may have changed and/or there has been a switch from reducing to oxidising groundwater conditions. These changes could be due to climatic influences (such as rainfall) which may affect recharge and consequently the nature of the groundwater at this coastal interface. In any case, the rate of increase in this bore is very low (0.04 mg/L per year) and concentrations of nitrate remain relatively low (<3 mg/L).

Overall, monitoring of groundwater quality on the northern Kapiti Coast has highlighted the need to confirm sources of nitrate in the groundwater and that there is a lack of knowledge about the influence of changes in land use practices on groundwater quality. Nitrogen isotope analysis could be used to determine if the source of nitrogen is from animal effluent or fertiliser. It would also be useful to age-date groundwater to determine if highly elevated concentrations of nitrate are a result of past or present land use practices.

7. Conclusions and recommendations

Sampling of 31 bores on the northern Kapiti Coast during November and December 2008 has indicated that nitrate concentrations in the groundwater are low to highly elevated. The greatest nitrate contamination is present in the unconfined aquifers in the Hautere groundwater zone, with some localised areas of high nitrate identified in the Waitohu groundwater zone. However, no nitrate concentration exceeded the DWSNZ (2005) MAV of 11.3 mg/L.

Two of the 31 bores sampled had counts of *E. coli* slightly above the DWSNZ (2005) MAV of <1 cfu/100mL. Both of these bores are located in shallow aquifers, with one used as a potable water supply. Samples from 26 bores were outside the DWSNZ (2005) guideline range for pH (7–8.5). However, the pH values measured were typical of New Zealand groundwaters. All other variables tested were below the DWSNZ (2005) MAVs or guideline values.

A comparison of groundwater monitoring data collected in 1996 and 2008 suggests that nitrate concentrations are now lower on the northern Kapiti Coast. However, areas which historically had nitrate contamination still have elevated nitrate concentrations. Many of these areas are in or downgradient of intensive land use (horticulture and agriculture) and consented discharges to land (animal and on-site wastewater) suggesting that these land use and activity types contribute to nitrate contamination of groundwater. However, further investigation using techniques such as nitrogen isotope and groundwater age analysis is required to confirm this.

Mann-Kendall trend analyses conducted on nitrate data from 10 GWSoE bores over 1993 to 2009 confirmed statistically significant and environmentally meaningful decreases (0.28-0.31 mg/L/yr) in nitrate concentrations in three bores located in areas of horticulture and one statistically significant increase in a bore located at Te Horo Beach settlement. The reason for these decreasing trends is uncertain but is probably related to changes in land and fertiliser use. The reason for the statistically significant increase (0.04 mg/L/yr) in nitrate concentrations in the bore at Te Horo Beach is also unclear. In any case, concentrations of nitrate in this bore remain relatively low (<3 mg/L).

The Hautere and Waitohu groundwater zones continue to be areas of concern as nitrate concentrations in some bores in these zones remain highly elevated. The extent of nitrate contamination is also unclear as a number of areas downgradient of consented discharges to land and intensive land use practices were not monitored as part of this investigation and limited monitoring has been conducted in shallow bores.

With the removal of agricultural wastewater discharges from streams to land, there is a growing need to provide protection for the region's soil and groundwater resources. Piezometric surveys of the northern Kapiti Coast suggest that with the removal of wastewater/effluent discharges to streams there is the potential for nutrients, if not properly managed, to migrate into surface water bodies with the flow of groundwater. Soil nutrient loadings and wastewater application rates must therefore be assessed carefully, particularly in areas of intensive land use.

7.1 Recommendations

1. Conduct piezometric contouring of the Waitohu groundwater zone to determine the direction of groundwater flow.

2. Obtain information on land use change and changes in land management practices such as fertiliser application for the northern Kapiti Coast.

3. Undertake further sampling of shallow groundwater bores located in the upper Hautere, mid-Coastal and Waitohu groundwater zones to investigate the extent of nitrate contamination in the shallow unconfined aquifer.

4. Undertake further sampling of groundwater downgradient of areas where highly elevated concentrations of nitrate were recorded (Hautere, Coastal and Waitohu groundwater zones).

5. Investigate the links between groundwater quality and surface water quality, in particular, the potential for nutrient migration from groundwater into surface water bodies, including wetland systems in the Coastal and Waitohu groundwater zones.

6. Investigate the use of nitrogen isotope analysis to determine the sources of nitrogen in areas of multiple land use.

7. Consider age-dating groundwater samples to help determine if contamination in aquifers is due to past or present land use.

8. Consider repeating a targeted investigation on the northern Kapiti Coast in 2013 to re-evaluate groundwater quality, especially nitrate concentrations.

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Appendix 1: Land cover in the northern Kapiti Coast catchment

Percentage of land cover or land use in northern Kapiti Coast calculated using Agribase Assurequality Database 2001 and Land Cover Database MfE 2001.

Land cover or land use	Percentage of cover
Indigenous forest	72.33
Exotic forest	2.91
Crops and horticulture	1.28
Sheep beef and deer farming	15.94
Dairy farming	6.32
Poultry farming	0.07
Urban areas	1.16

Appendix 2: Bore details and sampling results

Table A2.1: Targeted groundwater investigation results, November–December 2008

Bore No.	Bore Use	Groundwater Zone	Depth (m)	Easting	Northing	Date Sampled	Time Sampled (NZST)	Water Temperature (°C)	*E. coli* (cfu/100mL)	Total Nitrogen (mg/L)	Nitrite Nitrogen (mg/L)
R25/5261	Domestic	Coastal	5.9	2686311	6042429	24/11/2008	10:02	15.1	<1	0.63	0.0036
S25/5401	Potable, domestic	Waitohu	6	2694000	6046800	02/12/2008	08:36	14.3	2	<0.11	<0.002
R25/5255	Domestic	Waitohu	9.9	2689850	6049850	24/11/2008	13:18	14.5	<1	0.13	0.0053
R25/5256	Potable, domestic	Coastal	9	2686445	6045425	26/11/2008	11:30	15.8	<1	0.55	0.039
R26/6757	Irrigation	Coastal	7	2686163	6039107	24/11/2008	09:19	14.8	<1	0.52	0.0049
S25/5376	Irrigation	Waitohu	5	2691000	6051000	24/11/2008	14:25	15.7	<1	0.45	<0.002
R25/5245	Irrigation	Otaki	8	2689151	6048261	25/11/2008	13:04	13.7	<1	0.86	0.0024
S25/5225	Irrigation	Otaki	5	2693400	6044300	02/12/2008	11:25	13.9	<1	1.4	<0.002
R25/5161	Potable, domestic, irrigation, stock	Coastal	37	2687996	6043166	26/11/2008	12:48	14.6	<1	1.5	0.0053
S25/5269	Potable, domestic	Otaki	3	2693400	6045600	02/12/2008	09:30	13.2	<1	2.4	<0.002
R25/5175	Potable, domestic	Hautere	12.5	2689000	6041540	02/12/2008	08:57	15.8	<1	2.6	0.0034
S25/5428	Potable, domestic	Otaki	7	2692294	6046771	26/11/2008	11:15	15.7	<1	2.7	<0.002
R25/5257	Potable, domestic	Otaki	30	2689975	6046050	25/11/2008	13:50	15.7	<1	4.3	0.0051
S25/5427	Potable, domestic	Waitohu	18	2693764	6049312	26/11/2008	11:33	15.0	<1	5.3	0.0024
S25/5375	Potable, domestic	Waitohu	15	2693500	6051100	26/11/2008	10:33	14.6	<1	5.8	<0.002
R25/5177	Stock	Coastal	4.00	2689075	6044400	02/12/2008	09:30	15.6	<1	7.8	<0.002
R25/5244	Potable, domestic	Coastal	19.82	2689685	6045682	25/11/2008	14:28	16.4	<1	8.3	<0.002
S25/5252	Stock, irrigation	Hautere	20.8	2691235	6043500	24/11/2008	12:19	14.7	<1	8.8	<0.002
S25/5365	Not used	Hautere	7	2690100	6045550	25/11/2008	14:38	15.7	1	10	0.0022
R26/7110	Irrigation	Coastal	5	2684273	6039787	25/11/2008	10:02	20.2	<1	1.2	<0.002

Table A2.1 *cont*.: Targeted groundwater investigation results, November–December 2008

Bore No.	Nitrite-Nitrate Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	Ammoniacal Nitrogen (mg/L)	pH (Field)	Conductivity (Field) (µS/cm)	Dissolved Oxygen % Sat (Field)	Dissolved Oxygen (Field) (mg/L)
R25/5261	0.026	0.023	0.61	0.17	0.29	6.55	266	6.3	0.64
S25/5401	0.047	0.046	<0.10	0.0056	<0.01	4.85	80	43.1	4.41
R25/5255	0.09	0.085	<0.10	0.012	0.015	6.61	152	0.4	0.04
R25/5256	0.14	0.1	0.41	0.069	0.15	7.88	1,291	0	0
R26/6757	0.22	0.21	0.31	0.044	0.16	6.16	232	0.2	0.02
S25/5376	0.43	0.43	<0.10	0.036	<0.01	5.98	125	14.1	1.38
R25/5245	0.79	0.79	<0.10	0.007	<0.01	5.79	102	14.4	1.50
S25/5225	1.4	1.4	<0.10	0.012	<0.01	5.86	114	60.1	6.03
R25/5161	1.5	1.5	<0.10	0.013	<0.01	6.93	231	1.0	0.10
S25/5269	2.2	2.2	0.11	0.015	<0.01	5.62	162	12.1	1.27
R25/5175	2.5	2.5	0.18	0.0059	<0.01	5.57	169	16.8	1.63
S25/5428	2.6	2.6	<0.10	0.02	<0.01	6.35	208	43.2	4.29
R25/5257	4.3	4.3	<0.10	0.012	0.016	6.44	222	28.6	2.87
S25/5427	5.3	5.3	<0.10	0.046	<0.01	6.46	297	39.1	3.89
S25/5375	5.8	5.8	<0.10	0.064	<0.01	6.66	300	111	11.2
R25/5177	7.5	7.5	0.27	0.021	<0.01	5.35	185	52.6	5.24
R25/5244	8.2	8.2	<0.10	0.022	<0.01	5.61	236	77.5	7.48
S25/5252	8.8	8.8	<0.10	0.019	<0.01	5.95	233	73.3	7.23
S25/5365	10	10	<0.10	0.017	<0.01	6.03	247	42.7	4.17
R26/7110	<0.002	<0.002	1.2	0.71	0.81	7.13	513	0.2	0.02

Table A2.2: Groundwater State of the Environment sample results, December 2008

Bore No.	Bore Use	Groundwater Zone	Depth (m)	Easting	Northing	Date Sampled	Water Temperature (^{o}C)	*E. coli* (cfu/100mL)	Faecal Coliforms (cfu/100mL)
R25/5100	Irrigation	Coastal	48.2	2684570	6041166	02/12/2008	14.5	<1	<1
R25/5135	Irrigation	Hautere	93.27	2689170	6043198	02/12/2008	14.4		
R25/5164	Domestic	Coastal	0	2685891	6044082	02/12/2008	17.3	<1	<1
R25/5165	Domestic	Coastal	8	2686037	6043601	02/12/2008	14.8	<1	<1
R25/5190	Potable, domestic, stock	Coastal	0	2686696	6040703	02/12/2008	15.4	<1	<1
R25/5233	Irrigation, stock	Waitohu	18.7	2689415	6049279	01/12/2008	15.2	<1	<1
S25/5125	Irrigation	Otaki	10	2692751	6044728	01/12/2008	14.4	<1	<1
S25/5200	Irrigation	Hautere	45.8	2691200	6041500	01/12/2008	14.3	<1	<1
S25/5256	Irrigation	Hautere	30.78	2690508	6044868	03/12/2008	14.9		
S25/5322	Irrigation	Waitohu	27	2693000	6049200	01/12/2008	15.0	<1	<1

Bore No.	Nitrite Nitrogen (mg/L)	Nitrite-Nitrate Nitrogen (mg/L)	Nitrate Nitrogen (mg/L)	Dissolved Reactive Phosphorus (mg/L)	Ammoniacal Nitrogen (mg/L)	pH (Field)	Conductivity (Lab) (µS/cm)	Dissolved Oxygen % Sat (Field)	Dissolved Oxygen (Field) (mg/L)
R25/5100	0.0021	0.0053	0.0031	0.37	0.17	7.00	337	0	0
R25/5135	<0.0020	<0.0020	<0.002	0.47	0.33	7.29	588	0.1	0.01
R25/5164	0.0027	0.41	0.41	0.13	0.018	5.93	262	65.4	6.22
R25/5165	<0.0020	0.017	0.016	0.34	0.25	6.90	137	0.9	0.09
R25/5190	<0.0020	4.8	4.8	0.088	0.035	6.68	274	27.6	2.72
R25/5233	<0.0020	2	2	0.015	<0.010	6.00	151	30.4	3.02
S25/5125	<0.0020	2.5	2.5	0.018	0.023	5.80	134	42.3	4.25
S25/5200	<0.0020	0.0021	<0.002	0.15	0.028	6.60	278	0.1	0.01
S25/5256	<0.0020	9.6	9.6	0.02	<0.010	5.92	241	49	4.95
S25/5322	<0.0020	11	11	0.05	0.037	6.55	325	40	3.99

Table A2.3: Kapiti Coast District Council bore sampled 7 December 2008

Bore No.	Bore Use	Depth (m)	Easting	Northing	Date Sampled	Water Temperature (^{o}C)	Nitrate Nitrogen (mg/L)	Ammoniacal Nitrogen (mg/L)	pH (Field)
KCDC Bore 3	Water quality monitoring	2.89	2689705	6047232	07/12/2008	11.9	1.9	<0.01	5.6

Table A2.4: November 1996 targeted groundwater investigation results

Bore No.	Bore Use	Groundwater Zone	Depth (m)	Easting	Northing	Nitrate Nitrogen (mg/L)
S25/5348	Irrigation	Otaki	0.00	2692200	6046500	0.34
S25/5363	Irrigation	Hautere	4.20	2692225	6046825	1.50
S25/5349	Irrigation	Otaki	3.60	2692300	6046750	1.40
S25/5358	Irrigation	Otaki	5.20	2692325	6046800	2.30
S25/5362	Irrigation	Otaki	6.50	2692375	6046875	3.60
S25/5229		Hautere	0.00	2690287	6044907	16.0
R25/5148		Coastal	30.0	2689600	6044300	10.0
R25/5180	Domestic, irrigation	Hautere	30.0	2689975	6044775	8.60
S25/5359	Domestic, irrigation	Hautere	20.1	2690275	6045150	11.0
S25/5350	Domestic, irrigation	Hautere	18.20	2690370	6045075	15.0
S25/5240		Hautere	18.20	2689920	6044411	16.0
S25/5366	Domestic, irrigation, stock	Hautere	22.8	2690150	6045125	12.0
R25/5166		Hautere	0.00	2688875	6042750	8.50
S25/5342		Otaki	0.00	2690600	6045400	11.0
S25/5352	Irrigation	Hautere	0.00	2690500	6045600	8.70
S25/5365	Irrigation	Otaki	0.00	2690100	6045550	14.0
S25/5364	Irrigation	Otaki	0.00	2690050	6045750	2.80
R25/5177	Irrigation	Hautere	4.00	2689075	6044400	11.0
R25/5244	Irrigation	Coastal	0.00	2689685	6045682	10.0
R25/5257	Potable	Hautere	30.0	2689975	6046050	6.20
R25/5182	Irrigation	Hautere	0.00	2689125	6043725	9.40
R25/5139		Hautere	23.0	2689350	6045175	15.0
R25/5167		Coastal	0.00	2689150	6044750	17.0
S25/5250	Water quality monitoring	Hautere	0.00	2691600	6043650	0.18
S25/5252	Domestic, irrigation	Hautere	0.00	2691235	6043500	12.0
S25/5251	Irrigation	Hautere	0.00	2691950	6043875	0.14
S25/5244		Hautere	48.5	2691900	6044250	8.70
S25/5347	Irrigation	Hautere	0.00	2693400	6045600	3.30
R25/5175	Potable, domestic	Hautere	3.70	2689000	6041540	3.00
R25/5255	Irrigation	Otaki	9.00	2689850	6049850	0.05
R25/5176	Irrigation	Hautere	4.00	2688970	6041450	1.70
S25/5377	Potable, domestic, irrigation	Hautere	18.2	2691050	6050375	0.65
R25/5178	Irrigation	Hautere	7.30	2686100	6044000	0.90
S25/5384		Otaki	0.00	2695950	6050375	4.00
S25/5263		Otaki	0.00	2691500	6045500	4.20
R25/5181	Domestic, irrigation, stock	Coastal	24.2	2686350	6043100	0.05
R25/5259		Coastal	0.00	2689400	6046150	0.05
R25/7028		Otaki	10.0	2689095	6046419	0.05
R25/5256	Potable, domestic	Coastal	0.00	2686445	6045425	0.96
S25/5353		Waitohu	2.00	2694150	6049200	7.00
S25/5375	Potable, domestic	Waitohu	15.0	2693500	6051100	4.40

Table A2.4 *cont.*: November 1996 targeted groundwater investigation results

Bore No.	Bore Use	Groundwater Zone	Depth (m)	Easting	Northing	Nitrate Nitrogen (mg/L)
S25/5376	Irrigation	Otaki	4.20	2691000	6051000	0.05
R25/5179	Irrigation	Coastal	0.00	2687100	6042300	0.05
R25/5245	Irrigation	Otaki	6.10	2689151	6048261	1.30
S25/5360	Irrigation	Otaki	8.70	2691250	6047700	1.20
S25/5361	Irrigation	Otaki	6.80	2690300	6047950	2.10
S25/5249	Irrigation	Otaki	6.50	2693000	6044700	0.49
R25/5258	Irrigation	Hautere	15.3	2689825	6046300	9.20
S25/5241		Otaki	25.0	2692200	6044600	9.30
S25/5254	Irrigation	Hautere	20.0	2690800	6041600	0.14
S25/5255		Hautere	0.00	2691600	6041500	0.15
S25/5242		Hautere	20.3	2691900	6041900	7.10
			0.00	2692000	6045700	0.05
S25/5256	Irrigation	Otaki	30.5	2690508	6044868	14.0
S25/5125	Irrigation	Otaki	8.50	2692751	6044728	4.10
S25/5322	Irrigation	Otaki	26.6	2693100	6049200	14.0
R25/5233	Irrigation	Waitohu	18.6	2689415	6049279	2.90
S25/5354	Irrigation	Waitohu	7.90	2692709	6048864	2.80
S25/5355	Irrigation	Waitohu	40.0	2691900	6049100	0.05
Ray Taylor	Irrigation	Waitohu	12.1	2691900	6049100	2.00
S25/5357	Irrigation	Waitohu	2.50	2694400	6049600	4.20
S25/5311		Waitohu	30.6	2693800	6047500	0.47
S25/5320	Irrigation	Waitohu	59.9	2693120	6048917	0.05
S25/5329		Waitohu	25.3	2690600	6049700	0.22

Appendix 3: Groundwater quality variables and analytical methods

Laboratory	Variable	Method Used	Detection Limit
N/A	Temperature	Field meter – ExStik DO600 (Extech Imstruments), YSI 550A Meters and WTW350i Meters	0.01 ˚C
N/A	Dissolved Oxygen	Field meter – ExStik DO600 (Extech Imstruments), YSI 550A Meters and WTW350i Meters	0.01 mg/L
N/A	Conductivity	Field meter – ExStik DO600 (Extech Imstruments), YSI 550A Meters and WTW350i Meters	0.1 µS/cm
N/A	pH	Field meter – ExStik DO600 (Extech Imstruments), YSI 550A Meters and WTW350i Meters	0.01 units
Hills	pH	pH meter APHA 4500-H+ B 21st ed. 2005.	0.1 pH units
Hills	Electrical Conductivity	Conductivity meter, 25°C APHA 2510 B 21st ed. 2005.	0.1 mS/m, 1 µS/cm
Hills	Total Kjeldahl Nitrogen (TKN)	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} C (modified) 4500 NH3 F (modified) 21st ed. 2005.	0.10 mg/L
Hills	Total Nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N	0.050 mg/L
Hills	Total Ammoniacal-N	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
Hills	Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3 - I (modified) 21st ed. 2005.	0.002 mg/L
Hills	Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 mg/L
Hills	Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3 - I (modified) 21st ed. 2005.	0.002 mg/L
Hills	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
Hills/ELS	*E. coli*	APHA 21st ed. Method 9222 G	1 cfu/100 mL

Appendix 4: GWSoE nitrate results, 1993-2009

R25/5164		R25/5165		S25/5200		R25/5190	
Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)
22/09/1997	<0.01	16/03/1998	0.75	12/05/1993	<0.01	9/06/1999	4.6
9/12/1997	<0.01	15/06/1998	<0.01	07/04/1994	<0.01	12/10/1999	3
16/03/1998	0.02	21/09/1998	<0.01	13/07/1994	<0.01	18/09/2000	Not tested
15/06/1998	<0.01	14/12/1998	0.16	6/10/1994	0.01	11/12/2000	Not tested
21/09/1998	<0.01	22/03/1999	4.1	27/01/1995	<0.01	26/03/2001	Not tested
14/12/1998	<0.01	22/06/1999	0.02	02/05/1995	<0.01	24/09/2001	Not tested
22/03/1999	0.01	13/09/1999	0.63	04/08/1995	<0.01	21/03/2002	Not tested
22/06/1999	<0.01	20/12/1999	0.41	11/12/1995	<0.01	16/12/2002	Not tested
13/09/1999	<0.01	21/03/2000	3.4	27/03/1996	<0.01	26/03/2003	Not tested
20/12/1999	<0.01	19/06/2000	<0.01	16/09/1996	<0.01	23/06/2003	Not tested
19/06/2000	<0.01	18/09/2000	0.89	17/03/1997	<0.01	01/10/2003	6.57
18/09/2000	0.09	11/12/2000	5.8	22/09/1997	<0.01	17/12/2003	6.22
11/12/2000	0.02	26/03/2001	1.9	16/03/1998	<0.01	24/03/2004	12.6
26/03/2001	0.01	25/06/2001	0.3	21/09/1998	<0.01	14/06/2004	8.35
25/06/2001	0.01	24/09/2001	0.01	22/03/1999	<0.01	30/09/2004	6.42
24/09/2001	0.01	18/12/2001	0.03	13/09/1999	<0.01	14/12/2004	5.41
18/12/2001	0.03	19/03/2002	2.7	21/03/2000	0.08	21/03/2005	5.79
19/03/2002	0.03	24/06/2002	0.1	18/09/2000	0.01	02/08/2005	4.11
24/06/2002	0.03	17/09/2002	0.08	26/03/2001	0.01	06/10/2005	5.8
17/09/2002	0.03	16/12/2002	0.03	24/09/2001	0.01	13/12/2005	7.48
16/12/2002	0.08	26/03/2003	2.2	19/03/2002	0.03	22/03/2006	6.06
26/03/2003	0.03	23/06/2003	0.04	26/03/2003	0.03	12/07/2006	8.49
23/06/2003	0.03	01/10/2003	0.053	01/10/2003	0.015	27/09/2006	9.3
1/10/2003	0.006	17/12/2003	6.09	24/03/2004	0.005	14/03/2007	5.38
17/12/2003	<0.002	24/03/2004	1	14/06/2004	<0.002	22/06/2007	4.54
24/03/2004	0.005	14/06/2004	0.038	27/09/2004	0.026	12/09/2007	3.71
14/06/2004	0.004	27/09/2004	0.007	14/12/2004	0.014	19/12/2007	4.3
27/09/2004	0.002	14/12/2004	0.022	21/03/2005	0.003	28/02/2008	3.6
14/12/2004	0.118	21/03/2005	0.793	06/10/2005	<0.002	17/06/2008	3.5
21/03/2005	0.365	06/10/2005	0.003	13/12/2005	0.004	02/09/2008	4.8
6/10/2005	0.293	13/12/2005	0.007	30/03/2006	0.003	02/12/2008	4.8
13/12/2005	0.303	30/03/2006	0.335	11/07/2006	<0.002	03/03/2009	4.6
30/03/2006	0.219	12/07/2006	0.338	26/09/2006	<0.002		
12/07/2006	0.339	26/09/2006	0.024	20/06/2007	0.004		
26/09/2006	0.402	14/03/2007	1.23	11/09/2007	<0.002		
14/03/2007	0.642	22/06/2007	0.008	17/12/2007	0.0051		
22/06/2007	0.575	12/09/2007	0.038	27/02/2008	<0.002		
12/09/2007	0.47	19/12/2007	0.0091	16/06/2008	0.014		
19/12/2007	0.45	28/02/2008	0.033	01/09/2008	0.003		
28/02/2008	0.61	17/06/2008	0.026	01/12/2008	<0.002		
17/06/2008	0.41	02/09/2008	0.044	02/03/2009	0.0066		
2/09/2008	0.28	02/12/2008	0.016				
2/12/2008	0.41	03/03/2009	0.035				
3/03/2009	2.4						

S25/5125		R25/5233		R25/5100		R25/5135	
Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)
27/03/1996	10.8	26/06/1996	2.6	15/09/1993	0.02	12/05/1993	<0.01
26/06/1996	6.32	16/09/1996	1.9	23/11/1993	<0.01	15/09/1993	<0.01
16/09/1996	Not tested	11/12/1996	2.9	07/07/1994	<0.01	23/11/1993	0.01
2/12/1996	4.1	17/03/1997	2.7	27/01/1995	0.02	07/04/1994	<0.01
17/03/1997	Not tested	23/06/1997	2.3	02/05/1995	<0.01	06/10/1994	<0.01
23/06/1997	Not tested	22/09/1997	0.81	04/08/1995	<0.01	27/01/1995	0.02
22/09/1997	Not tested	09/12/1997	0.59	11/12/1995	<0.01	02/05/1995	<0.01
9/12/1997	Not tested	16/03/1998	0.43	27/03/1996	<0.01	04/08/1995	<0.01
16/03/1998	Not tested	15/06/1998	0.33	16/09/1996	<0.01	11/12/1995	<0.01
15/06/1998	Not tested	21/09/1998	0.94	17/03/1997	<0.01	27/03/1996	<0.01
29/07/1998	9.7	14/12/1998	2.4	23/06/1997	<0.01	16/09/1996	<0.01
21/09/1998	Not tested	22/03/1999	0.6	22/09/1997	<0.01	17/03/1997	<0.01
22/10/1998	10	22/06/1999	0.37	16/03/1998	<0.01	13/07/1997	<0.01
14/12/1998	Not tested	13/09/1999	1.9	21/09/1998	<0.01	22/09/1997	<0.01
24/02/1999	4.7	20/12/1999	0.52	14/12/1998	<0.01	16/03/1998	<0.01
22/03/1999	1.7	21/03/2000	2.1	22/03/1999	<0.01	21/09/1998	<0.01
22/06/1999	4.1	19/06/2000	0.36	13/09/1999	<0.01	22/03/1999	<0.01
13/09/1999	5.9	18/09/2000	0.49	21/03/2000	<0.01	13/09/1999	<0.01
20/12/1999	4.7	11/12/2000	0.67	18/09/2000	0.01	20/03/2000	<0.01
21/03/2000	1.7	26/03/2001	1.4	26/03/2001	0.01	18/09/2000	0.01
19/06/2000	6.3	25/06/2001	1.3	24/09/2001	0.01	26/03/2001	0.01
18/09/2000	Not tested	24/09/2001	1.3	19/03/2002	0.03	24/09/2001	0.01
11/12/2000	2.8	18/12/2001	1.1	17/09/2002	0.03	19/03/2002	0.03
26/03/2001	0.91	19/03/2002	1.2	26/03/2003	0.03	17/09/2002	0.03
25/06/2001	1.3	24/06/2002	1.7	01/10/2003	0.023	26/03/2003	0.03
24/09/2001	Not tested	17/09/2002	2.1	24/03/2004	0.006	01/10/2003	<0.002
18/12/2001	6.8	16/12/2002	2.2	14/06/2004	0.009	24/03/2004	0.023
19/03/2002	2.2	26/03/2003	2.4	30/09/2004	0.022	14/06/2004	<0.002
24/06/2002	7.5	23/06/2003	1.7	14/12/2004	0.023	27/09/2004	<0.002
17/09/2002	4.9	01/10/2003	1.39	23/03/2005	<0.002	14/12/2004	0.086
26/03/2003	Not tested	17/12/2003	1.77	02/08/2005	0.014	21/03/2005	0.004
23/06/2003	Not tested	24/03/2004	2.79	06/10/2005	<0.002	06/10/2005	0.004
1/10/2003	5.17	14/06/2004	2.65	13/12/2005	<0.002	13/12/2005	0.004
17/12/2003	2.79	27/09/2004	2.56	22/03/2006	0.007	30/03/2006	0.004
24/03/2004	5.27	14/12/2004	2.62	12/07/2006	<0.002	12/07/2006	<0.002
14/06/2004	2.05	21/03/2005	2.43	26/09/2006	<0.002	26/09/2006	<0.002
27/09/2004	6.31	02/08/2005	1.87	14/03/2007	<0.002	14/03/2007	<0.002
14/12/2004	5.09	05/10/2005	1.47	22/06/2007	<0.002	20/06/2007	0.003
21/03/2005	1.83	13/12/2005	1.24	12/09/2007	<0.002	11/09/2007	<0.002
2/08/2005	3.38	30/03/2006	1.11	19/12/2007	<0.002	19/12/2007	<0.002
5/10/2005	2.82	11/07/2006	1.03	28/02/2008	<0.002	27/02/2008	<0.002
13/12/2005	2.07	26/09/2006	1.18	17/06/2008	<0.002	17/06/2008	0.0025
21/03/2006	0.824	14/03/2007	2.07	02/09/2008	<0.002	02/09/2008	<0.002
11/07/2006	6.61	20/06/2007	1.81	02/12/2008	0.0031	02/12/2008	<0.002
26/09/2006	3.87	11/09/2007	1.46	03/03/2009	0.0033	03/03/2009	0.0049
14/12/2006	4.31	17/12/2007	1.2				
28/02/2007	2.17	27/02/2008	1.4				
20/06/2007	0.85	16/06/2008	1.7				

S25/5125		R25/5233		R25/5100		R25/5135	
Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)
11/09/2007	3.07	01/09/2008	1.6				
17/12/2007	2.1	01/12/2008	2				
27/02/2008	2.1	02/03/2009	1.7				
16/06/2008	1.9						
1/09/2008	4.4						
1/12/2008	2.5						
2/03/2009	2.6						

S25/5256		S25/5322	
Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)
12/05/1993	11.3	12/05/1993	13.9
15/09/1993	12	15/09/1993	15
24/11/1993	14	23/11/1993	14
07/04/1994	14.5	07/04/1994	14.1
13/07/1994	12.9	13/07/1994	13.1
06/10/1994	13	06/10/1994	13
27/01/1995	14	27/01/1995	14
04/08/1995	15	02/05/1995	13
11/12/1995	15	29/06/1995	12.2
27/03/1996	12.8	04/08/1995	14
26/06/1996	14.9	11/12/1995	14
16/09/1996	Not tested	27/03/1996	14.6
11/12/1996	13.2	26/06/1996	14.4
17/03/1997	Not tested	16/09/1996	Not tested
23/06/1997	Not tested	2/12/1996	14
22/09/1997	Not tested	17/03/1997	Not tested
09/12/1997	Not tested	23/06/1997	13
28/01/1998	12	22/09/1997	13.6
16/03/1998	Not tested	09/12/1997	12.7
22/04/1998	12	16/03/1998	12.9
15/06/1998	Not tested	15/06/1998	14.2
29/07/1998	12	21/09/1998	12.8
21/09/1998	Not tested	14/12/1998	Not tested
22/10/1998	12	22/03/1999	13.5
14/12/1998	Not tested	22/06/1999	13.1
24/02/1999	12	13/09/1999	12.2
22/03/1999	Not tested	20/12/1999	13
23/03/1999	Not tested	21/03/2000	12.9
09/06/1999	11	19/06/2000	12.7
22/06/1999	Not tested	18/09/2000	Not tested
13/09/1999	Not tested	11/12/2000	12.5
12/10/1999	11	26/03/2001	13.1
20/12/1999	9	25/06/2001	11.8
21/03/2000	11.6	24/09/2001	Not tested
19/06/2000	11.9	18/12/2001	11.8
18/09/2000	11.2	19/03/2002	12.2

S25/5256		S25/5322	
Date	NO_3-N (mg/L)	Date	NO_3-N (mg/L)
11/12/2000		24/06/2002	11.7
26/03/2001	10.9	17/09/2002	12.2
25/06/2001	9.5	16/12/2002	Not tested
24/09/2001	10.5	26/03/2003	Not tested
18/12/2001	10.9	23/06/2003	Not tested
19/03/2002	11	01/10/2003	10.3
27/06/2002	10.6	17/12/2003	9.8
17/09/2002	Not tested	24/03/2004	9.7
16/12/2002	Not tested	14/06/2004	10.1
26/03/2003	Not tested	27/09/2004	9.4
23/06/2003	Not tested	14/12/2004	10.6
01/10/2003	9.93	21/03/2005	11.3
17/12/2003	9.3	02/08/2005	10.8
27/09/2004	9.5	05/10/2005	9.8
14/12/2004	10.5	13/12/2005	9.5
21/03/2005	11.5	21/03/2006	9.4
02/08/2005	10.9	11/07/2006	9.9
05/10/2005	9.8	26/09/2006	10.2
13/12/2005	9.2	14/12/2006	10.6
21/03/2006	8.8	28/02/2007	11.4
11/07/2006	9.93	20/06/2007	10.4
26/09/2006	9.94	11/09/2007	9.63
14/12/2006	10.5	17/12/2007	9.3
28/02/2007	9.91	27/02/2008	9.9
20/06/2007	9.95	16/06/2008	9.5
11/09/2007	9.94	01/09/2008	11
19/12/2007	9.2	01/12/2008	11
27/02/2008	10	02/03/2009	10
01/09/2008	9		
03/12/2008	9.6		
04/03/2009	9.1		

Appendix 5: Temporal trend results

Trend analyses were performed using NIWA's Time Trend Software (Version 3 2009).

Mann-Kendall test for Group R25/5100 O'Malley for Nitrate Nitrogen

Period analysed 15 years and 7 months for calendar years 1993 to 2009

45 observations from 15/09/93 to 3/03/09 with 35 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5100	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.01	-35.00	7299.00	-0.40	0.69	0.00	0.00	0.00

Mann-Kendall test for Group R25/5135 Windsor Park for Nitrate Nitrogen

Period analysed 15 years and 11 months for calendar years 1993 to 2009

45 observations from 12/05/93 to 3/03/09 with 39 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5135	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.01	-34.00	5479.33	-0.45	0.66	0.00	0.00	0.00

Mann-Kendall test for Group R25/5164 Card for Nitrate Nitrogen

Period analysed 11 years and 7 months for calendar years 1997 to 2009

44 observations from 22/09/97 to 3/03/09 with 22 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5164	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.03	567.00	9467.67	5.82	0.00	0.04	0.02	0.05

Mann-Kendall test for Group R25/5165 Saulter for Nitrate Nitrogen

Period analysed 11 years and 1 months for calendar years 1998 to 2009

43 observations from 16/03/98 to 3/03/09 with 6 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5165	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.04	-146.00	9118.67	-1.52	0.13	-0.01	-0.04	0.00

Mann-Kendall test for Group R25/5190 Williams for Nitrate Nitrogen

Period analysed 9 years and 10 months for calendar years 1999 to 2009

24 observations from 9/06/99 to 3/03/09 with 2 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5190	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	5.39	-74.00	1623.33	-1.81	0.07	-0.35	-0.67	-0.03

Mann-Kendall test for Group R25/5233 OP Trust for Nitrate Nitrogen

Period analysed 12 years and 10 months for calendar years 1996 to 2009

51 observations from 26/06/96 to 2/03/09 with 9 ties

Sample size greater than 10 and normal approximation used to determine P value

R25/5233	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	1.60	117.00	15143.67	0.94	0.35	0.04	-0.02	0.09

Mann-Kendall test for Group S25/5125 Bettys for Nitrate Nitrogen

Period analysed 13 years and 1 months for calendar years 1996 to 2009

42 observations from 27/03/96 to 2/03/09 with 4 ties

Sample size greater than 10 and normal approximation used to determine P value

S25/5125	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	3.63	-239.00	8510.33	-2.58	0.01	-0.29	-0.49	-0.12

Mann-Kendall test for Group S25/5200 Common Property for Nitrate Nitrogen

Period analysed 15 years and 11 months for calendar years 1993 to 2009

41 observations from 12/05/93 to 2/03/09 with 32 ties

Sample size greater than 10 and normal approximation used to determine P value

S25/5200	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	0.01	64.00	5354.00	0.86	0.39	0.00	0.00	0.00

Mann-Kendall test for Group S25/5256 Penray for Nitrate Nitrogen

Period analysed 15 years and 11 months for calendar years 1993 to 2009

49 observations from 12/05/93 to 4/03/09 with 18 ties

Sample size greater than 10 and normal approximation used to determine P value

S25/5256	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	10.90	-753.00	13412.33	-6.49	0.00	-0.28	-0.32	-0.23

Mann-Kendall test for Group S25/5322 Edhouse for Nitrate Nitrogen

Period analysed 15 years and 11 months for calendar years 1993 to 2009

56 observations from 12/05/93 to 2/03/09 with 21 ties

Sample size greater than 10 and normal approximation used to determine P value

S25/5322	Median value	Kendall statistic	Variance	Z	P	Median annual Sen slope	5% confidence limit	95% confidence limit
Unadjusted	12.20	-1018.00	19973.33	-7.20	0.00	-0.31	-0.35	-0.27

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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Photo Credit
Groundwater sampling

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