



# Annual groundwater monitoring report for the Wellington region, 2008/09

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# Annual groundwater monitoring report for the Wellington region, 2008/09

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## 1. Introduction

Groundwater in the Wellington region is highly valued for a variety of uses. Groundwater under the Lower Hutt Valley alone supplies about a third of Wellington's<sup>1</sup> water supply. Otaki, Waikanae<sup>2</sup>, Martinborough, Carterton<sup>3</sup> and Greytown<sup>4</sup> also rely on groundwater for public supply. In rural areas of the Kapiti Coast and the Wairarapa, groundwater is an important water source for domestic supply, stock water and irrigation. Groundwater is also an important water source for many springs and wetlands, and the successful protection of these groundwater dependant ecosystems requires careful management of groundwater use.

To assist with the sustainable management of groundwater resources in the Wellington region, Greater Wellington Regional Council (Greater Wellington) conducts regular monitoring of groundwater levels and quality. This report summarises the results of monitoring undertaken over the period 1 July 2008 to 30 June 2009 inclusive. A report containing a detailed analysis of long-term trends is produced every six years (see Jones & Baker 2005).

As groundwater recharge in the region is strongly influenced by rainfall and river flows, it is recommended that this report is read in conjunction with the 2008/09 annual hydrology monitoring report (Keenan & Gordon 2009).

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<sup>1</sup> Groundwater is usually used to supply Lower Hutt and supplements supplies to Wellington City's Central Business District, and southern and eastern suburbs. It may also be used to supplement supplies to Upper Hutt and Porirua.

<sup>2</sup> In Waikanae, the Kapiti Coast District Council uses groundwater as a backup water supply to its surface water take from the Waikanae River.

<sup>3</sup> Primary supply to Carterton is from surface water.

<sup>4</sup> Primary supply to Greytown is from surface water.

## 2. Overview of the groundwater monitoring programme

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

Groundwater management zones have been defined in all principal and some secondary groundwater areas (Figure 2.1). These have been used as a framework for describing groundwater areas in this report.

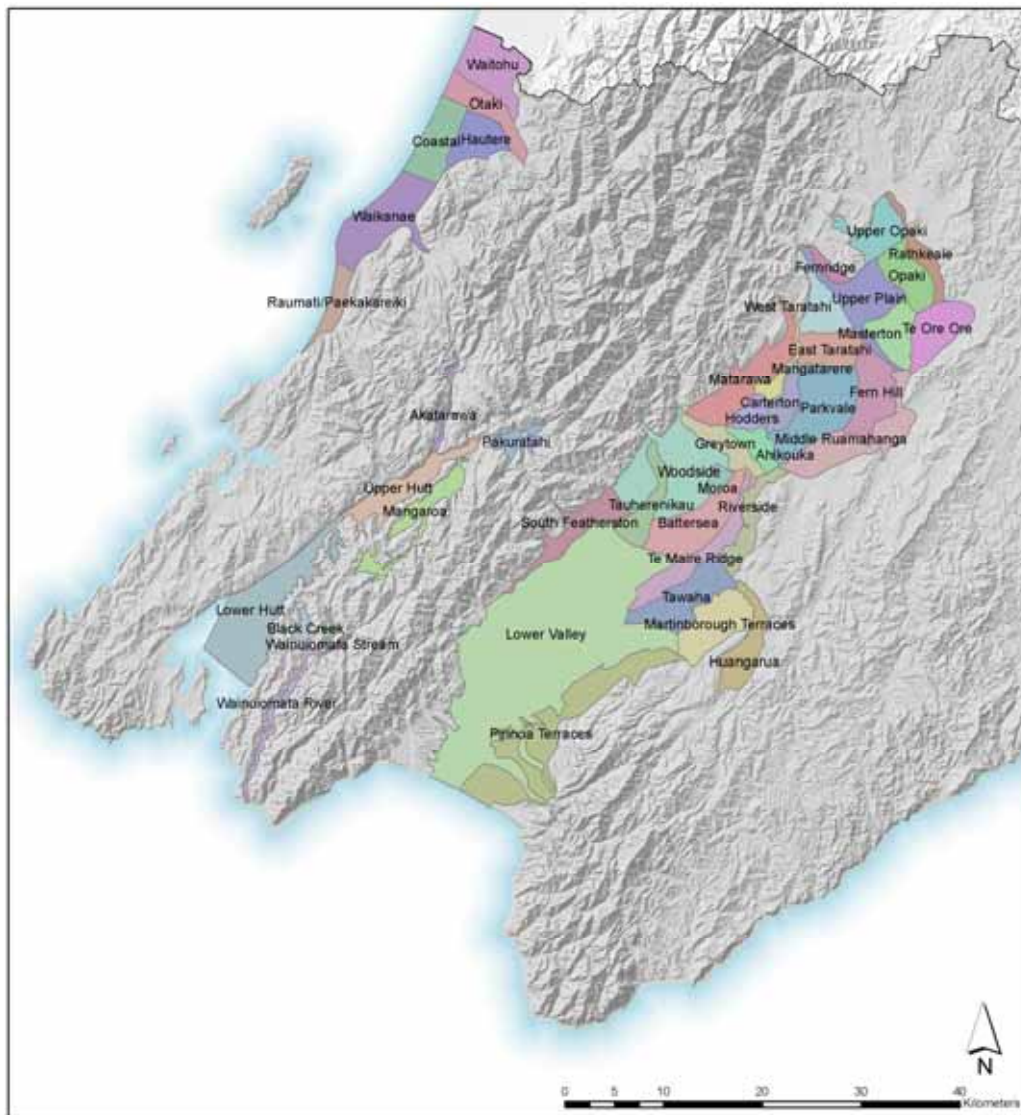


Figure 2.1: Groundwater management zones in the Wellington region

## 2.1 Objectives

The aims of Greater Wellington's groundwater monitoring programme are to:

- Provide information on the baseline quantity and quality of groundwater;
- Describe the current state of Greater Wellington's groundwater resource at a regional scale;
- Assist in the detection of spatial and temporal changes in groundwater quantity and quality;
- Recommend the suitability of groundwater for designated uses; and
- Provide a mechanism to determine the effectiveness of policies and plans.

## 2.2 Monitoring network

Greater Wellington monitors a network of boreholes for groundwater level and quality. This network utilises dedicated monitoring boreholes as well as used<sup>5</sup> and un-used<sup>6</sup> privately owned boreholes. The groundwater level network currently consists of 75 automatic and 72 manually dipped<sup>7</sup> boreholes (Figure 2.2 and Appendix 1).

The core groundwater quality monitoring network, referred to as the Groundwater State of the Environment (GWSOE) network, comprises 71 boreholes (Figure 2.3, Appendix 1), sampled quarterly for a wide range of physico-chemical and microbiological variables. A full list of groundwater quality variables monitored, together with details of field and analytical methods, is provided in Appendix 2.

Other selected groundwater level and quality monitoring is carried out on a project-specific basis (e.g., Tidswell 2008, Tidswell 2009).

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<sup>5</sup> Boreholes that are currently pumped for water supply (this pumping may have short term effects on water level readings).

<sup>6</sup> Boreholes previously pumped for supply but no longer utilised for this purpose.

<sup>7</sup> Boreholes are manually dipped to test depth to groundwater, generally on a four or six week rotation.

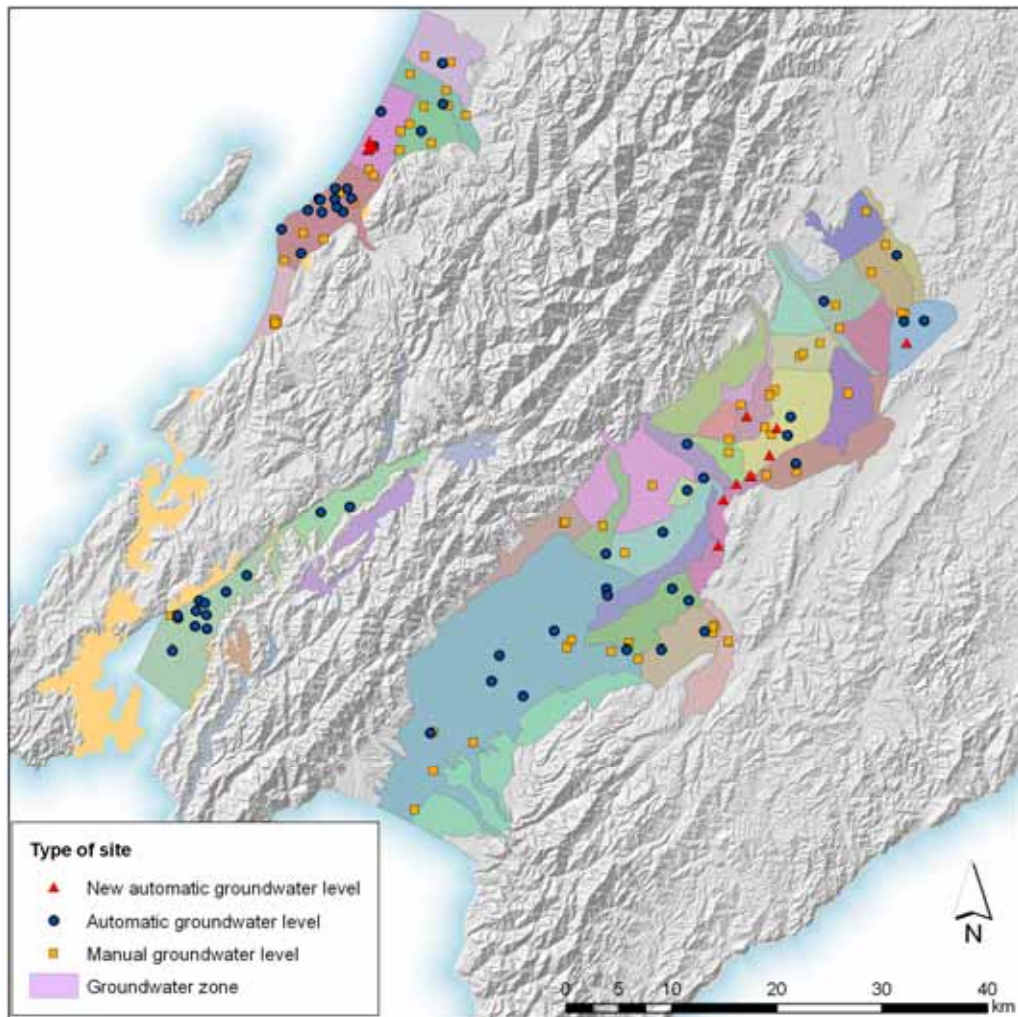


Figure 2.2: Location of groundwater level sites in the Wellington region monitored over 1 July 2008 to 30 June 2009, including new automatic groundwater level monitoring sites installed in the Wairarapa Valley and on the Kapiti Coast

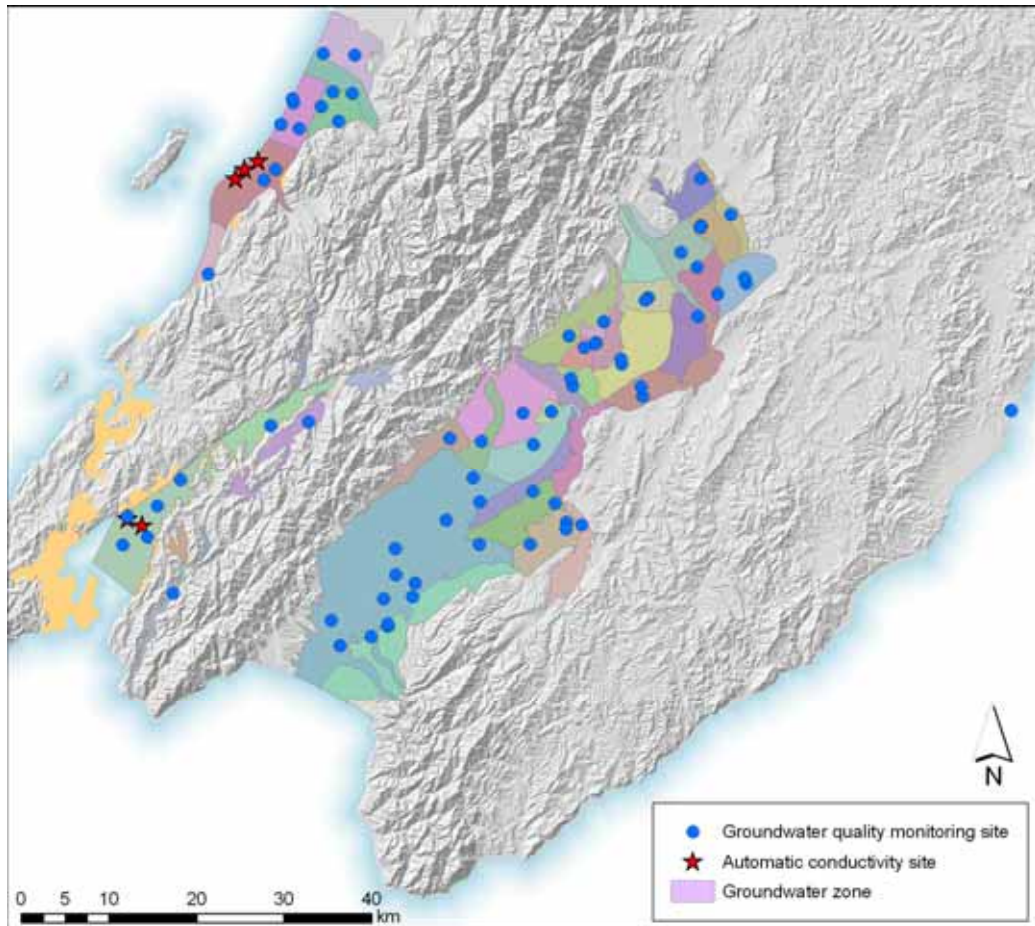


Figure 2.3: Location of existing routine groundwater quality monitoring sites in the Wellington region. Automated saline intrusion groundwater monitoring sites are also shown.

### 2.2.1 Changes to the monitoring network in 2008/09

The following major changes to the groundwater monitoring network were made during the year:

- A new water quality monitoring borehole at Riversdale was added to the GWSOE network in September 2008 to increase the network's spatial coverage of the region (Figure 2.2).
- As part of the Wairarapa groundwater investigation (see Section 3.2), 11 new monitoring boreholes were constructed in 2008. These bores were located to provide hydrogeological data in areas with critical 'gaps' in the current monitoring network. Electronic logging equipment was installed in these wells during 2008/09 (Figure 2.2).
- Monitoring equipment was also installed in the Te Hapua wetland on the Kapiti Coast to better understand the relationship between the wetland system and the coastal groundwater aquifers. In March 2009, two new boreholes were drilled (Figures 2.2, 2.4 & 2.5) and two existing boreholes were added to the groundwater level network. In addition, equipment was installed to monitor water levels in the wetland directly. The project is



sponsored by both Greater Wellington and the Kapiti Coast District Council with support from Friends of Te Hapua Wetland community group.



Figure 2.4: Hand-drilling a new borehole next to the Te Hapua wetland on the Kapiti Coast in March 2009 (left) and the final installation, with borehole in the foreground (green box) and wetland staff gauge protruding from open water



Figure 2.5: Wetland water level gauge installed at Te Hapua wetland on the Kapiti Coast

### 3. Groundwater quantity

#### 3.1 Groundwater level monitoring

Aquifers are recharged by either rainfall infiltration or leakage of water from rivers. In some cases aquifers may receive recharge from both sources in different proportions. For this reason the amount of rainfall and river flow directly influences groundwater levels in aquifers. This is particularly evident in shallow (unconfined) aquifers, but also has a subdued effect in deeper (confined) aquifers<sup>8</sup>. Examples of rainfall and river flow trends in 2008/09 for Kapiti and the Wairarapa are shown in Figure 3.1 – for further information refer to Keenan & Gordon (2009).

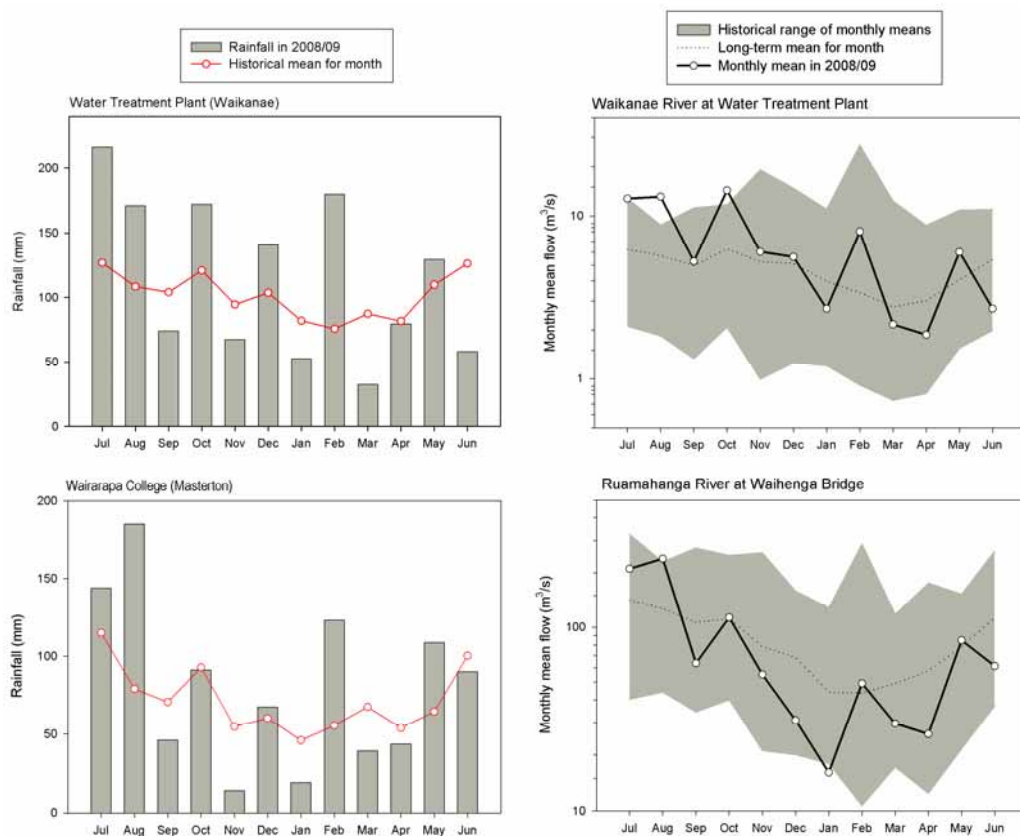


Figure 3.1: Left – monthly rainfall totals for 2008/09 (grey bars) compared to historical mean monthly rainfall (red line) at two rainfall monitoring locations in the Wellington region. Right – monthly mean river flows for 2008/09 (black line) compared to historical mean monthly rainfall (dotted line) for the Waikanae and Ruamahanga rivers (grey area represents the range of historical monthly mean river flows).

The 2008/09 year had few extremes in terms of groundwater levels with very few record low levels recorded at monitoring sites across the region. Levels in some aquifers that had been showing decreasing trends in recent years made a partial recovery during the year. These results are evident in groundwater level

<sup>8</sup> Deeper aquifers are recharged through the downward percolation of water from shallow aquifers.

plots (Figures 3.2-3.3), with groundwater levels in a number of the boreholes around or above average.

The summer drought of 2007/08 that persisted into autumn 2008 has not been reflected in groundwater level data, suggesting that the wet 2008 winter replenished aquifers. Frequent storms throughout July 2008 brought regular rainfall to the region (Keenan & Gordon 2009). The above average rainfall for winter could be described as a significant groundwater recharge event. This event is evident in a number of graphs shown in Figure 3.2 and Figure 3.3, with increases in monthly average groundwater levels during July and August 2008.

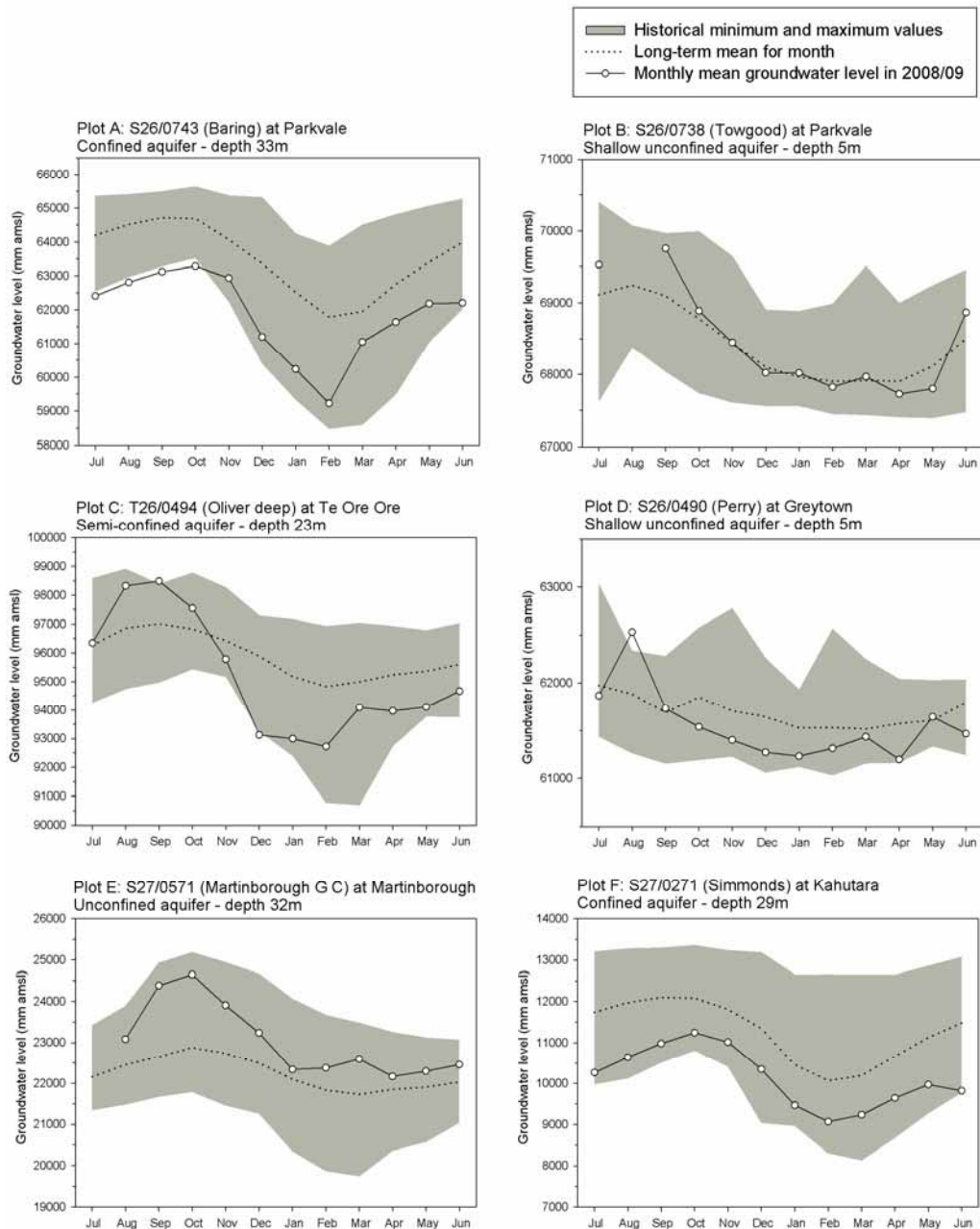


Figure 3.2: Monthly mean groundwater levels for 2008/09 (black line) compared to historical mean monthly groundwater levels (dotted line) at selected sites in the Wairarapa. The grey shaded areas represent the range of historical minimum and maximum monthly mean groundwater levels.

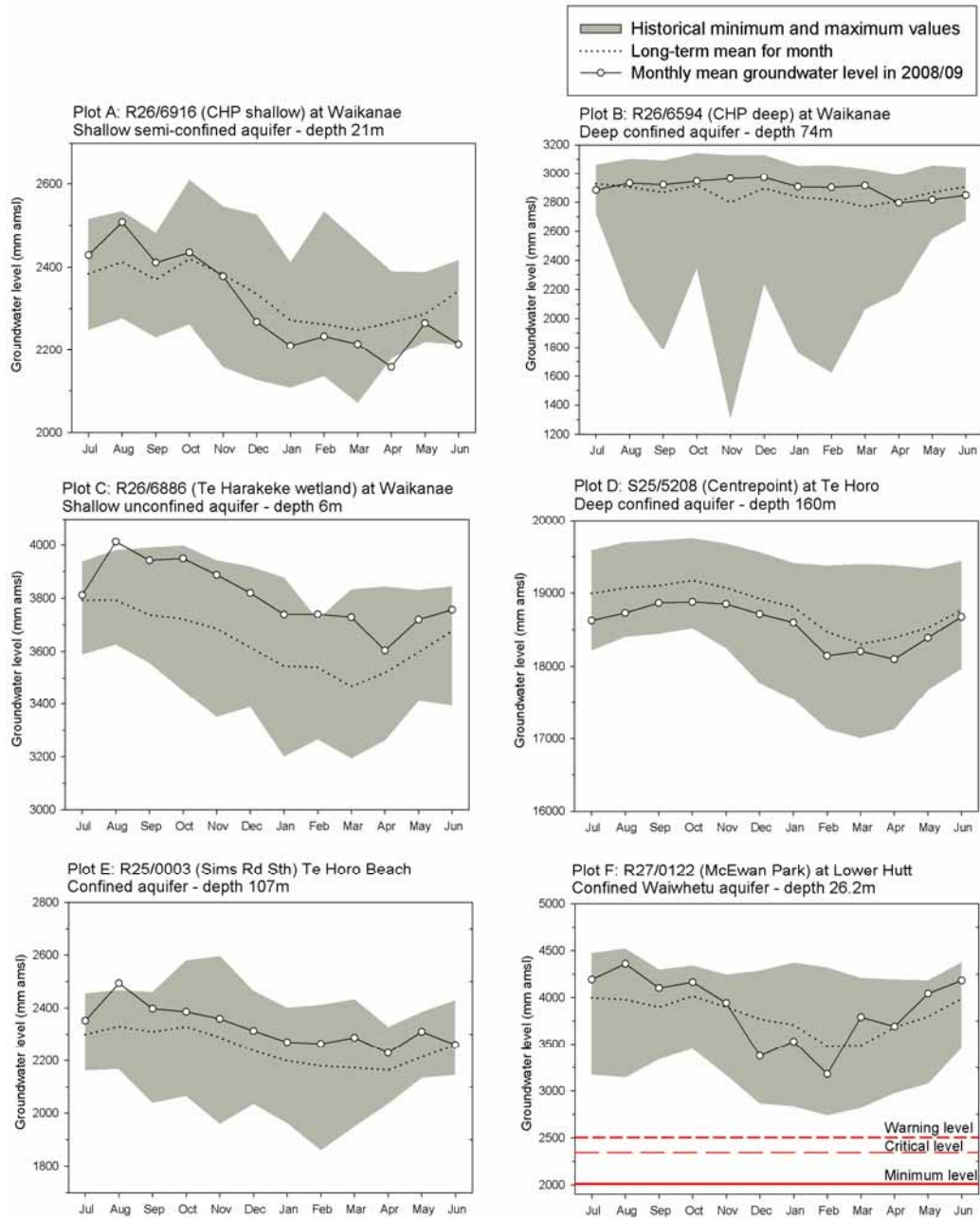


Figure 3.3: Monthly mean groundwater levels for 2008/09 (black line) compared to historical mean monthly groundwater levels (dotted line) at selected sites in Kapiti and Lower Hutt. The grey shaded areas represent the range of historical minimum and maximum monthly mean groundwater levels.

Spring 2008 (September to November) was characterised by alternating months of settled dry weather followed by above average wet periods. This explains the relatively average groundwater levels with wet and dry months balancing each other out.

December 2008 was characterised by average to above average rainfall conditions in the west of the region, and relatively dry conditions in eastern Wairarapa (Keenan & Gordon 2009). This explains the higher than average levels over this period in Kapiti Coast aquifers compared to some Wairarapa aquifers.

Alternating dry and wet periods continued through to the end of summer 2008/09 and the beginning of autumn 2009. The drought conditions declared in the eastern Wairarapa during autumn had no significant effect on Wairarapa aquifer levels.

### 3.1.1 Wairarapa

Groundwater levels were lower in monitoring sites in the Wairarapa Valley compared to other sites in the region over the year. However, a partial recovery in levels was seen in some aquifers which over recent years had been showing decreasing trends. The Parkvale confined aquifer (Figure 3.2, Plot A), while still well below average, had successive months from November 2008 to June 2009 where groundwater levels were above the long term minimum. This recovery was also evident in the Te Ore Ore deep aquifer monitoring site (Figure 3.2, Plot C) where significant pressure from groundwater abstraction has in the previous years resulted in record low levels. The Martinborough Terraces aquifer (Figure 3.2, Plot E) remained above average throughout the entire year, indicating the drought declared in the eastern hill country in autumn did not significantly affect aquifer levels.

It is probable that the wet winter of 2008 played a major role in the partial recovery in water levels observed in most Wairarapa groundwater monitoring sites. High rainfall in February 2009 may also have reduced groundwater abstraction and therefore contributed to less seasonal decline than normal. However, monitoring in stressed aquifers in the Wairarapa Valley indicates water levels are still below long term averages. The Wairarapa groundwater models (discussed in Section 3.2) may help define in future whether abstraction or climate is the driving force in controlling groundwater levels in each major aquifer system in the Wairarapa Valley.

### 3.1.2 Lower Hutt

An average year in terms of groundwater levels occurred in the Lower Hutt aquifer system. Levels were well above warning levels for saline intrusion (Figure 3.3, Plot F).

### 3.1.3 Kapiti Coast

Rainfall and river flow conditions during 2008/09 on the Kapiti Coast led to above average groundwater levels in a large number of the monitoring sites. This is particularly evident in shallow unconfined aquifers, with levels associated with the Te Harakeke wetland in Waikanae (Figure 3.3, Plot C) and Te Hapua wetland in Te Horo reaching their highest levels since monitoring began in 2005 and 2004 respectively.

The Waikanae potable borefield had no significant use during the year and therefore there was no significant associated groundwater level drops in the Waikanae aquifer (Figure 3.3, Plot B). New trigger levels have been developed by Kapiti Coast District Council and Greater Council to further safeguard the Waikanae aquifer during borefield operation. These trigger levels will be in operation during the 2009/10 summer period.

Groundwater levels in the 160-m deep Centrepoint borehole in the Te Horo area were above record minima for the entire year. In previous years levels at this site have shown a minor decreasing trend. Although groundwater levels are still below the long-term average for this site, the higher levels is a positive sign as it suggests groundwater level recovery. With no significant changes in groundwater abstraction in this area it is likely that climate is still a dominant controlling factor on water levels in this aquifer system.

### **3.2 Wairarapa groundwater investigation**

As reported by McAlister & Tidswell (2008), the Wairarapa groundwater investigation was initiated in response to increasing demand for groundwater for irrigation in the Wairarapa over the last decade and a need to review the allocation limits. Significant progress has been made over the last year, with computer models developed for the lower, middle and upper sections of the Wairarapa Valley (Figure 3.4). The models, which simulate the groundwater and surface water environment, are in their final calibration and reporting phase.

The models will allow us to test a range of water abstraction and climatic scenarios that will help to determine sustainable groundwater limits in the upcoming review of our Regional Freshwater Plan.

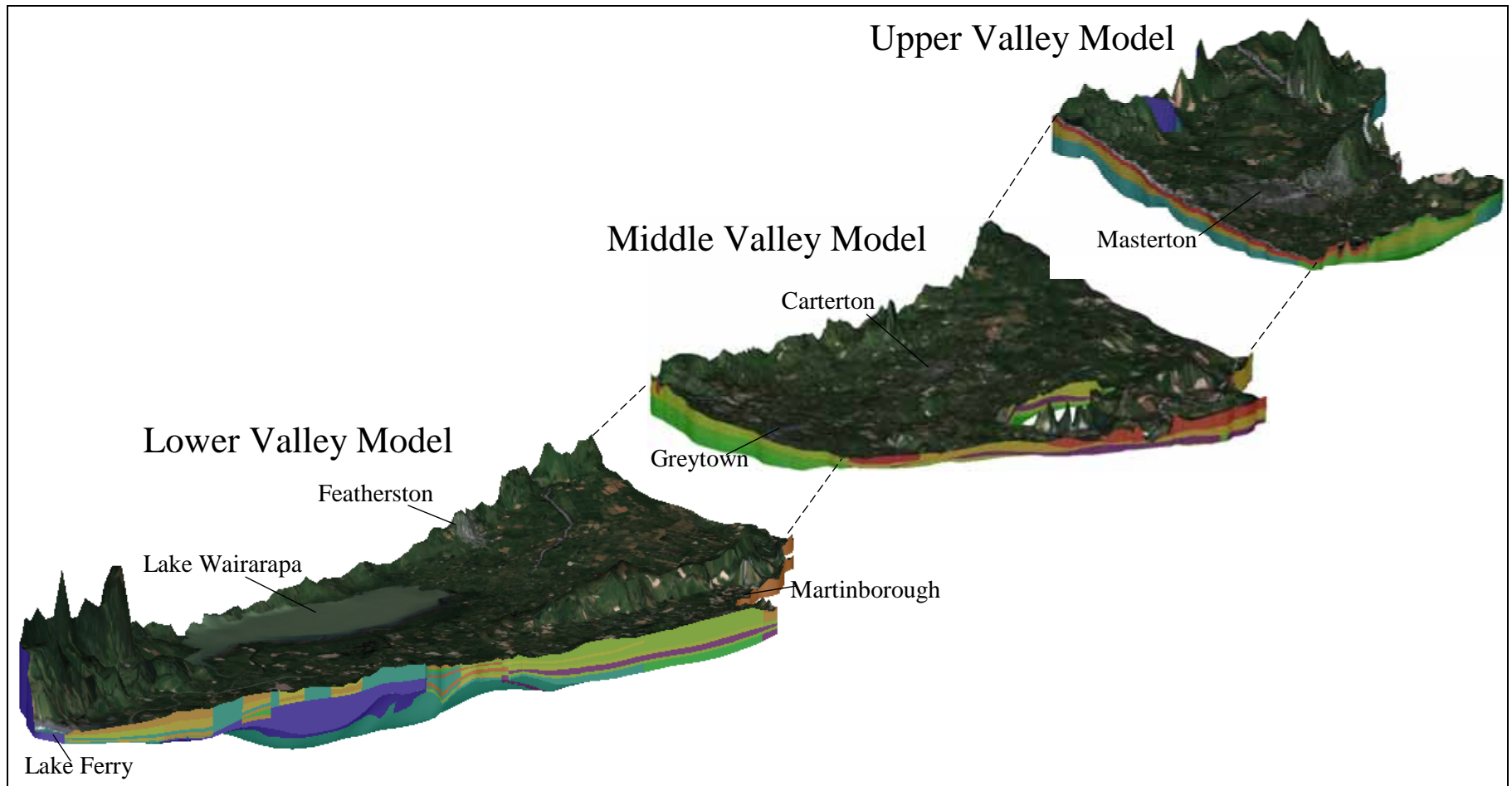


Figure 3.4: Schematic three-dimensional representation of the three modelled Wairarapa groundwater areas. Different groundwater units (aquifers and aquitards) are represented by coloured bands beneath ground level. The vertical axis in this image has been stretched by 25 times. The Wairarapa was separated into the three areas based on hydraulic flow divides at the Waingawa River and south of Greytown.

## 4. Groundwater quality

This section provides a brief overview of the results of groundwater quality monitoring conducted in the Wellington region over 2008/09. This includes both routine groundwater state of the environment (GWSOE) monitoring and targeted groundwater quality investigations.

Water 'quality' is a difficult concept to define, even though it is a commonly used term. The quality of groundwater can be described through the analysis of physical, chemical and microbiological variables. The GWSOE programme analyses a range of these variables, including dissolved oxygen, conductivity, pH, faecal bacteria, major ions, nutrients, and trace metals.

There are a number of human factors that influence groundwater quality, notably land use (e.g., additional inputs of nutrients from agriculture, horticulture, effluent disposal) and in some cases water abstraction. However, natural variables such as the source of the water (rainfall or river), aquifer geology and residence time of water in the aquifer also influence groundwater quality.

### 4.1 GWSOE monitoring – key findings

As outlined in subsection 2.2, Greater Wellington routine groundwater quality monitoring involves quarterly sampling of 71 boreholes across the region (Figure 4.1). With only four sets of sampling results per year, a comprehensive evaluation of all of the data is not undertaken on an annual basis. Therefore comments in this report are restricted to two key indicators of groundwater contamination arising from landuse intensification and/or on-site wastewater disposal: nitrate-nitrogen (nitrate) and *Escherichia coli* (*E. coli*) bacteria. In addition, the results of one-off testing for a small number of heavy metals and metalloids in groundwater samples from all 71 boreholes are summarised in this section.



Figure 4.1: Filtering a sample during routine groundwater monitoring



#### 4.1.1 Nitrate-nitrogen (nitrate)

Based on median values recorded over 2008/09, 11 of 71 (15.5%) GWSOE boreholes recorded elevated (3–7 mg/L)<sup>9</sup> concentrations of nitrate (Figure 4.2). A further six boreholes in Kapiti and the upper Wairarapa Valley recorded median nitrate concentrations in the relatively high range (7–11.3 mg/L). Groundwater samples from three of these boreholes exceeded the Ministry of Health Drinking Water Standards (DWSNZ 2005) maximum acceptable value (MAV) of 11.3 mg/L on one sampling occasion. The highest nitrate concentration recorded was 16 mg/L in borehole T26/0538. Nitrate concentrations of 12 mg/L were recorded in boreholes S26/0223 and T26/0489. All three boreholes are located in the upper Wairarapa Valley. Only borehole S26/0223 is used for potable water supply.

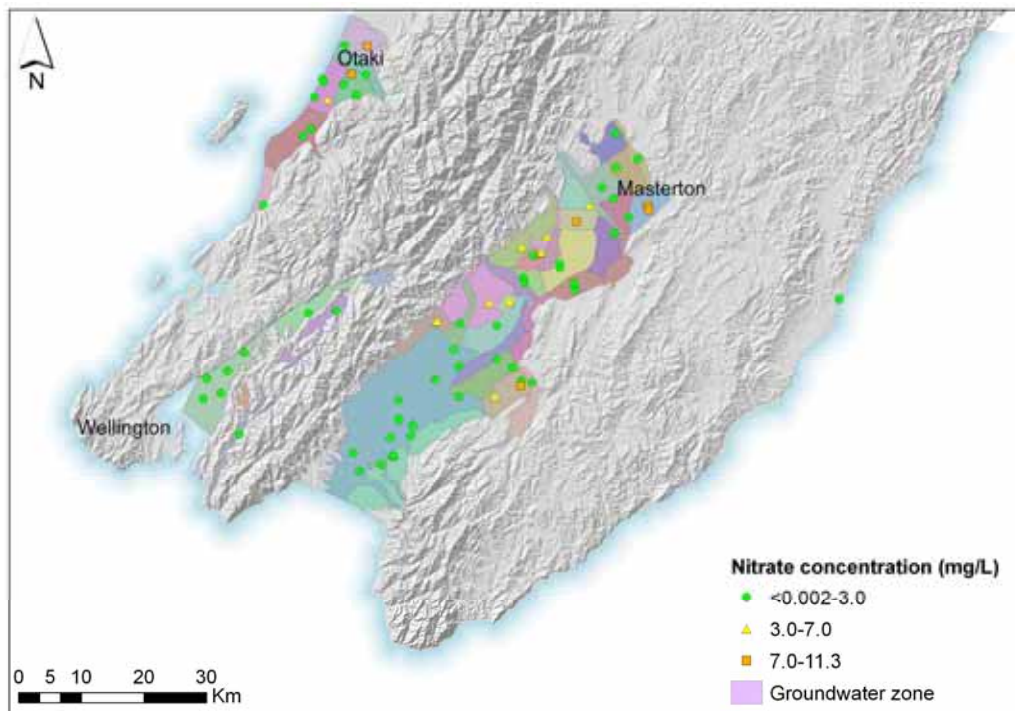


Figure 4.2: Median nitrate nitrogen concentrations recorded in GWSOE monitoring boreholes sampled over 2008/09

Overall, nitrate contamination was recorded in boreholes where results have historically been elevated and in areas of intensive agriculture (Wairarapa) and horticulture (Kapiti Coast). The wide ranging depth of the boreholes with elevated nitrate concentrations (<5m to 54m) suggests that nitrate contamination is not limited to shallow unconfined aquifers but is able to migrate into deeper aquifer systems<sup>10</sup>.

<sup>9</sup> While most groundwater in New Zealand rarely has background nitrate-nitrogen concentrations exceeding 1 mg/L (Close et al. 2001), in this report 3 mg/L NO<sub>3</sub>-N is used as an indicator of anthropogenic influence in order to increase certainty caused by variability. A threshold concentration of 3 mg/L was also used by Madison & Brunett (1985) and Close et al. (2001).

<sup>10</sup> This is particularly evident in recharge areas, with elevated nitrate concentrations not commonly found in deeper confined aquifers.

Groundwater is also known to discharge to a number of surface water bodies throughout the region and there is the potential that groundwater discharge high in nitrogen could contribute to the decline of surface water quality. The Australian and New Zealand guidelines (ANZECC) 2000 are commonly used to assess physico-chemical and microbiological aspects of surface water quality in New Zealand streams and rivers. If groundwater concentrations of nitrate are compared to the ANZECC (2000) trigger value for lowland ecosystem (0.444 mg/L), then median nitrate concentrations in 37 of the 71 GWSOE boreholes were above the ANZECC (2000) trigger level.

#### 4.1.2 *E. coli*

The DWSNZ (2005) use *E. coli* as an indicator of contamination of drinking water by faecal material<sup>11</sup>. For drinking water supplies, *E. coli* counts should be <1 cfu/100 mL.

*E. coli* was detected in 10 boreholes on 13 occasions during four rounds of GWSOE sampling over 2008/09 (Figure 4.3). The highest *E. coli* count was 3,000 cfu/100mL (R25/5164) at Te Horo Beach in the Coastal Zone of Kapiti. Te Horo Beach is a small settlement reliant on onsite wastewater treatment systems for effluent disposal. Previous studies involving dry tracer tests have confirmed that groundwater at Te Horo Beach is able to move from wastewater

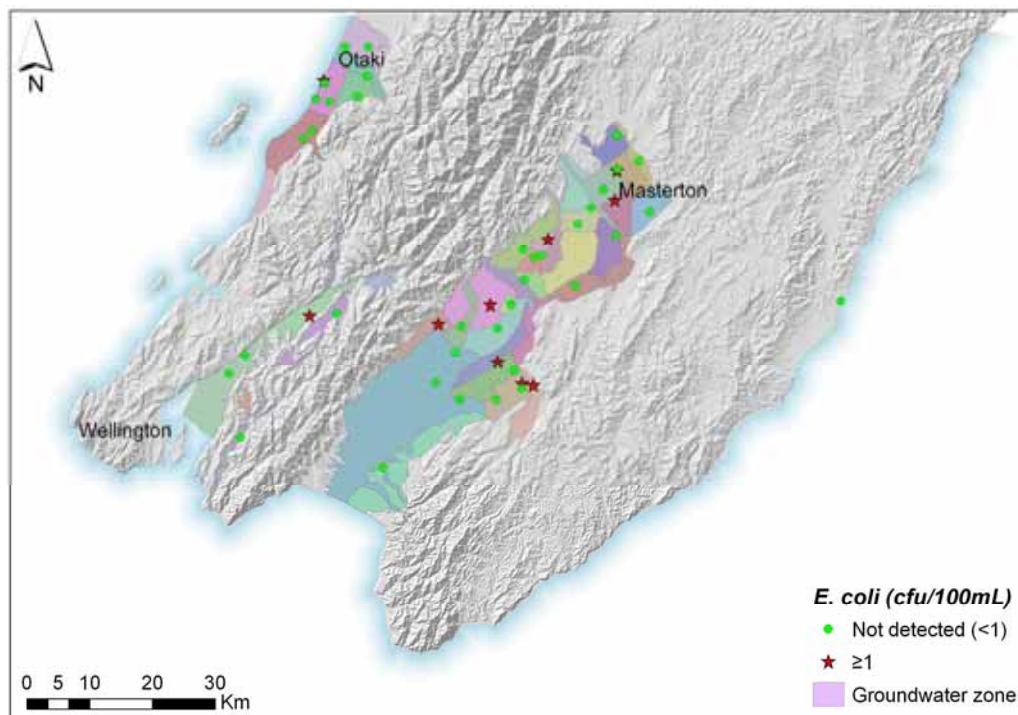


Figure 4.3: Detection (on one or more sampling occasions) of *E. coli* bacteria in GWSOE boreholes sampled quarterly over 2008/09

<sup>11</sup> It is impracticable to monitor water supplies for all potential human pathogens, so surrogates are used to indicate possible contamination from such things as human and animal excrement, these being the most frequent causes of health-significant microbial contamination in drinking water supplies.

treatment systems to nearby boreholes relatively quickly (Hughes 1998). It is possible that the microbial contamination occurring at R25/5164 is due to the borehole's proximity to a nearby wastewater treatment system. This borehole is not used as a potable drinking water supply. Other noteworthy readings were 300 cfu/100 mL (again recorded in borehole R25/5164), 36 cfu/100 mL (S27/0136) in Woodside (west of Greytown) and 34 cfu/100mL (S27/0389) in Martinborough Eastern Terraces. The latter two boreholes are located in areas of intensive landuse and one has poor borehead protection<sup>12</sup>.

#### 4.1.3 Heavy metals and metalloids

Dissolved lead and zinc are routinely analysed in GWSOE samples. In addition, during March 2009, groundwater samples were tested for dissolved arsenic, cadmium, copper, chromium and nickel.

Arsenic was detected in samples from 20 boreholes, with concentrations in three non-potable boreholes (38-44 m deep) in the Wairarapa Valley exceeding the DWSNZ (2005) MAV of 0.02 mg/L (Figure 4.4). In general the boreholes arsenic was found in were greater than 10m deep, and were in the Wairarapa Valley and on the Kapiti Coast. There were two exceptions; low concentrations of arsenic were detected in shallow coastal boreholes at Riversdale and Te Horo Beach.

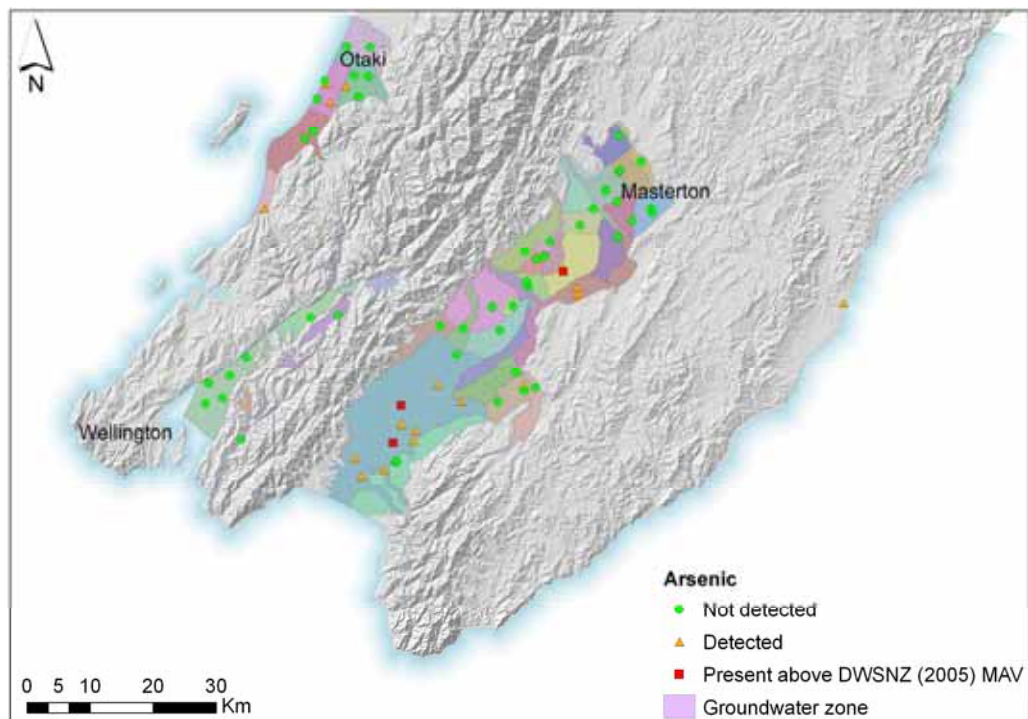


Figure 4.4: Dissolved arsenic concentrations recorded in GWSOE samples collected in March 2009

<sup>12</sup> Bacteria and viruses can contaminate groundwater supplies if surface water runoff, animals and debris are able to enter the well or bore. Contamination of groundwater can be reduced by securing the area around the well/bore head.

Given that the geology of the Wellington region consists of mainly greywacke and marine-derived sediments, it is possible that arsenic is occurring naturally in the groundwater. Pesticides, timber treatment sites and old sheep and cattle dip sites can contribute to anthropogenic sources of arsenic in groundwater (Rosen 2001).

Cadmium, chromium, copper, nickel, lead and zinc were detected in samples from some boreholes but all concentrations were below DWSNZ (2005) MAV or guideline values.

## 4.2 Targeted investigations

In addition to routine monitoring under the GWSoE programme, some specific groundwater quality investigations were also undertaken over 2008/09. These included one-off testing of groundwater boreholes on the northern Kapiti Coast for nutrients and faecal bacteria and a combined surface water and groundwater investigation of water quality in the Mangatarere catchment, Carterton.

### 4.2.1 Kapiti groundwater quality investigation

The Kapiti Coast groundwater quality investigation was undertaken in late 2008 and involved one-off testing of water samples from 31 boreholes for dissolved nutrients and faecal bacteria. The investigation targeted the impacts on groundwater quality of intensive farming and horticultural development as well as the expansion of properties at Te Horo Beach serviced by on-site wastewater treatment systems.

Results from the investigation are reported in detail by Tidswell (2009). Nitrate-nitrogen (nitrate) contamination was found to exist to various degrees in the area studied. The most widespread contamination was 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 (concentrations up to 11 mg/L). Samples from a number of boreholes recorded nitrate concentrations of at least half the MAV (11.3 mg/L).

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

### 4.2.2 Mangatarere catchment investigation

In September 2008, Greater Wellington commenced a 12-month integrated study of the Mangatarere catchment in Carterton. Water quality in the lower

reaches of the Mangatarere Stream is amongst the poorest in rivers and streams in the Wellington region, particularly in terms of dissolved nutrient concentrations. The catchment is subject to multiple stressors, including high water abstraction and reduced flows in summer, intensive land use (dairy farming and a large piggery) and the discharge of treated wastewater from Carterton township.

The principal aim of the Mangatarere investigation is to better understand water quality within the catchment, with the view to determining the primary nutrient sources and the potential migration of nutrients from the soil zone to groundwater aquifers to surface water. The groundwater component of the investigation involved two-monthly testing of water quality in 13 boreholes. At the time of finalising this report, the last sampling round was being completed. The results of the investigation will be reported in 2010.

## 5. Summary

Groundwater levels were generally above average on the Kapiti Coast, average in the Hutt Valley and around average to below average in the Wairarapa. This mirrors rainfall and river flow data for 2008/09 reported by Keenan & Gordon (2009), although in a slightly muted way. The alternating months of dry and wet during the year sustained fairly average groundwater levels throughout the region. Some water level recovery was recorded in deeper confined aquifers, although these still tracked below long term averages, particularly in the Wairarapa.

Routine groundwater quality monitoring over 2008/09 indicated that *E. coli* bacteria counts met the Ministry of Health drinking water standard in the majority of the 71 boreholes monitored, with bacteria detected in only 10 boreholes (and generally on only one sampling occasion). Median nitrate concentrations were low (<3 mg/L) in most boreholes. However, median concentrations in six boreholes located in Kapiti and Wairarapa were high (7-11.3 mg/L) and samples from three of these boreholes exceeded the Ministry of Health drinking water standard on one sampling occasion. Elevated nitrate results were generally seen in shallow boreholes in areas of intensive farming and horticulture.

One-off testing of groundwater for metals in March 2009 found that dissolved concentrations of cadmium, chromium, copper, nickel, lead and zinc were below DWSNZ (2005) MAV or guideline values in all 71 boreholes tested. Arsenic was detected in samples from 20 boreholes, with concentrations above the DWSNZ (2005) MAV (0.01 mg/L) in three samples. Arsenic is possibly occurring naturally in these bores from water-rock interaction with greywacke-derived sediments and marine sediments.

Results from a targeted investigation on the northern Kapiti Coast suggest that nitrate concentrations have decreased significantly in some boreholes since 1996. However, elevated groundwater concentrations of nitrate still remain in many of the boreholes located in the Waitohu and Hautere groundwater zones.

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## Appendix 1: Groundwater monitoring networks

Table A1.1: Greater Wellington's automatic groundwater level monitoring network

Site Name	Site Number	Groundwater Zone	Start Date
<b>Wairarapa Valley</b>			
Simmonds /John	S27/0099	Battersea	10/12/1996
Perry	S26/0490	Greytown	13/08/1990
Hammond	S27/0225	Greytown	06/09/1994
Simmonds - 6E/44/30/I	S27/0309	Kahutara	11/01/2002
Simmonds - 6E/51/18/I	S27/0317	Kahutara	21/12/2001
Green	S27/0467	Kahutara	29/11/2001
Martinborough Golf Club	S27/0571	Martinborough Eastern Terraces	05/10/1998
Duggan	S27/0522	Martinborough Western Terraces	01/12/2000
Blundell	S26/0749	Middle Ruamahanga	17/12/1997
Croad	S27/0202	Moroa	26/04/1988
Luttrell/Shallow	S27/0587	Onoke	07/09/1990
Towgood	S26/0738	Parkvale	03/08/1983
Baring	S26/0743	Parkvale	06/11/1986
Dry River Beef	S27/0481	Pukeo	19/09/1983
Zyzalo	T26/0239	Rathkeale	26/08/1997
Burt	S27/0330	Tauherenikau	30/11/2000
Herrick	S27/0381	Tawaha East	09/03/1984
Smith	S27/0346	Tawaha West	02/12/1983
Wairoria	S27/0434	Te Hopai	02/02/1994
Oliver - deep	T26/0494	Te Ore Ore	27/11/1991
Oliver - shallow	T26/0501	Te Ore Ore	15/07/1983
Robinson	S27/0442	Tuhitarata	30/08/2005
Downing	S26/0033	Upper Plain	30/09/1983
Wairio	S27/0428	Wairio	11/02/1983
Lower Parkvale at Renall - deep	S26/1032	Parkvale	29/09/08
Lower Parkvale at Renall - shallow	S26/1033	Parkvale	29/09/08
Hilton Road - deep	S26/1034	Carterton	14/11/08
Hilton - shallow	S26/1035	Carterton	14/11/08
Lucas	T26/0814	Te Ore Ore	05/08/08
Taumata Lagoon - Inner	S27/0881	Middle Ruamahanga	29/08/09
Taumata Lagoon - Outer	S27/0878	Middle Ruamahanga	04/08/09
Bicknell	S27/0883	Ahikouka	07/08/08
Tucker	S27/0884	Riverside	14/08/08
Didsbury	S27/0885	Riverside	07/08/08
McNamara - Shallow	S26/1053	Parkvale	21/8/08
<b>Hutt Valley</b>			
HVMTC	R27/0120	Lower Hutt GW Zone	24/09/1968
McEwan Park Shallow	R27/0122	Lower Hutt GW Zone	03/03/1971
IBM No 1	R27/0320	Lower Hutt GW Zone	14/02/1974
UWA 3	R27/1086	Lower Hutt GW Zone	24/12/1997
Hutt Rec	R27/1115	Lower Hutt GW Zone	15/12/1967
Mitchell Park	R27/1116	Lower Hutt GW Zone	24/09/1968
Taita Intermediate	R27/1117	Lower Hutt GW Zone	24/09/1968
Randwick	R27/1122	Lower Hutt GW Zone	22/07/1975
Somes Island	R27/1171	Lower Hutt GW Zone	28/01/1969
IBM No 2	R27/1265	Lower Hutt GW Zone	16/09/2004
Marsden St	R27/6386	Lower Hutt GW Zone	01/05/2001
South Pacific Tyres	R27/1137	Upper Hutt GW Zone	08/06/2006
Trentham Memorial Park	R27/7004	Upper Hutt GW Zone	25/05/1973
McEwan Park Deep	R27/7153	Lower Hutt GW Zone	14/03/2008



Site Name	Site Number	Groundwater Zone	Start Date
TS Tamatoa Deep	R27/7215	Lower Hutt GW Zone	5/02/2008
TS Tamatoa Shallow	R27/7154	Lower Hutt GW Zone	5/02/2008
<b>Kapiti Coast</b>			
Sims Rd Sth	R25/0003	Coastal GW Zone	28/03/1985
Housiaux 2	R26/6879	Coastal GW Zone	23/02/2005
Centrepoint	S25/5208	Hautere GW Zone	19/12/1991
Bettys	S25/5258	Otaki GW Zone	04/03/1993
Waikanae Park	R26/6284	Waikanae GW Zone	14/07/2003
Rangihiroa St	R26/6287	Waikanae GW Zone	16/12/2002
Rutherford Drive	R26/6378	Waikanae GW Zone	13/09/2006
Stevenson	R25/5171	Coastal GW Zone	15/04/2009
Jensen Deep	R25/5262	Coastal GW Zone	26/03/2009
J Abigail & J Anderton	R25/7087	Coastal GW Zone	30/03/2009
Jensen Shallow	R25/7086	Coastal GW Zone	30/03/2009
Estuary Shallow	R26/6566	Waikanae GW Zone	18/02/2005
Waikanae CHP Deep	R26/6594	Waikanae GW Zone	30/05/1994
Taiata St Shallow	R26/6673	Waikanae GW Zone	18/02/2005
Larch Grove	R26/6831	Waikanae GW Zone	01/03/2001
Maclean Park	R26/6833	Waikanae GW Zone	03/04/2001
Te Harakeke No 3	R26/6886	Waikanae GW Zone	18/11/2005
Waikanae CHP Shallow	R26/6916	Waikanae GW Zone	10/08/1994
Taiata St Deep	R26/6955	Waikanae GW Zone	18/02/2005
Estuary Deep	R26/6956	Waikanae GW Zone	18/02/2005
Nga Manu	R26/6991	Waikanae GW Zone	18/11/2005
K6	R26/6992	Waikanae GW Zone	18/11/2005
W1	R26/7025	Waikanae GW Zone	18/11/2005
Taylors	S25/5332	Waitohu GW Zone	23/05/1995

Table A1.2: Greater Wellington's manual groundwater level monitoring network

Site Name	Site No.	Groundwater Zone	Start Date
<b>Wairarapa</b>			
Craig /Deep	S26/0545	Ahikouka	03/08/1983
Craig /Shallow	S26/0547	Ahikouka	03/08/1983
Nicholson	S26/0223	East Taratahi	18/03/1998
East Coast Fert./Dee	S26/0229	East Taratahi	14/05/1984
Oldfield	S26/0236	East Taratahi	03/08/1983
East Coast Fert./Shall	S26/0242	East Taratahi	03/08/1983
McKay	T26/0326	Fern Hill	03/08/1991
Simmonds /Jim	S27/0271	Kahutara	21/04/1982
Awaroa /Deep	S27/0446	Kahutara	11/11/1982
Awaroa /Shallow	S27/0465	Kahutara	20/04/1982
Wither/Craig	S26/0658	Mangatarere	03/08/1983
Wall	S27/0403	Martinborough Eastern Terraces	13/11/2001
Collins/MacCullum	S27/0560	Martinborough Eastern Terraces	01/05/2002
Te Kairanga/Deep	S27/0640	Martinborough Eastern Terraces	01/02/2002
Transport Wairarapa	T26/0429	Masterton	10/02/1986
Wenden	S26/0756	Middle Ruamahanga	29/05/1998
Morrison	S27/0248	Middle Ruamahanga	03/08/1983
Warren	S27/0594	Narrows	18/08/1981
Luttrell /Deep	S27/0576	Onoke	29/11/1982
Tocher/Lawrence	T26/0208	Opaki	26/01/1998
Tulloch /Shallow	S26/0155	Parkvale	03/08/1983
Denbee	S26/0568	Parkvale	17/08/1983

Site Name	Site No.	Groundwater Zone	Start Date
Tulloch /Investigation	S26/0656	Parkvale	03/08/1983
McNamara	S26/0675	Parkvale	30/10/1996
Ness /Deep	S27/0484	Pukeo	07/12/1990
Ness/Shallow	S27/0485	Pukeo	28/11/1995
Stuart	S27/0517	Pukeo	22/09/1989
Windy Farm /House	S27/0009	South Featherston	01/05/2002
Windy Farm /Pig Unit	S27/0012	South Featherston	03/08/1983
Sth Featherston School	S27/0035	Tauherenikau	03/08/1983
Butcher	S27/0542	Tawaha	21/12/1988
Waicon	T26/0232	Te Ore Ore	19/09/1983
List	S27/0572	Huangarua Lower Terraces	
Masterton District Council	T26/0243	Te Ore Ore	26/09/1988
Annear	R28/0002	Turanganui	14/11/2001
Lenton	T26/0003	Upper Opaki	02/04/1997
Dick /Investigation	S26/0030	Upper Plain	24/07/1989
Atkinson	S27/0618	Whangaeahu / Tuhitarata	16/04/1982
Carlisle	S27/0148	Woodside	03/08/1983
<b>Hutt Valley</b>			
Nevis St	R27/1223	Lower Hutt GW Zone	03/03/1971
<b>Kapiti Coast</b>			
Faith P	R25/5123	Coastal GW Zone	26/02/1993
Quinn	R26/6747	Coastal GW Zone	30/06/1982
Housiaux 1	R26/6861	Coastal GW Zone	25/11/2004
Housiaux 2b	R26/6936	Coastal GW Zone	25/11/2004
Housiaux 3	R26/6880	Coastal GW Zone	25/11/2004
Housiaux 5	R26/6882	Coastal GW Zone	25/11/2004
Housiaux 6	R26/6883	Coastal GW Zone	25/11/2004
Housiaux 4	R26/6881	Coastal GW Zone	22/09/2004
Jamieson	R25/5111	Hautere GW Zone	26/02/1993
Windsor Park	R25/5135	Hautere GW Zone	30/06/1982
Common Property	S25/5200	Hautere GW Zone	12/03/1993
Penray	S25/5256	Hautere GW Zone	26/02/1993
KCDC Rangijuru	R25/5228	Otaki GW Zone	08/04/1993
Lutz C	S25/5212	Otaki GW Zone	23/03/1993
Andrews V	S25/5228	Otaki GW Zone	26/02/1993
Horowhenua Racing Club	S25/5287	Otaki GW Zone	12/03/1993
QE Park No 3	R26/5102	Raumati/Paekak GW Zone	12/09/2001
QE Park No 1	R26/6503	Raumati/Paekak GW Zone	26/02/1993
QE Park No 2	R26/6520	Raumati/Paekak GW Zone	12/12/1994
QE Park No 4	R26/6919	Raumati/Paekak GW Zone	12/09/2001
QE Park No 5	R26/6920	Raumati/Paekak GW Zone	12/09/2001
Weka Park	R26/6521	Waikanae GW Zone	26/02/1993
Mazengarb	R26/6557	Waikanae GW Zone	26/03/1993
NZ Staff College	R26/6569	Waikanae GW Zone	26/02/1993
McLaughlan	R26/6626	Waikanae GW Zone	26/02/1993
McCardle	R26/6738	Waikanae GW Zone	26/02/1993
Te Harakeke Bore 1	R26/6884	Waikanae GW Zone	14/05/2002
Te Harakeke Bore 2	R26/6885	Waikanae GW Zone	14/05/2002
Edhouse D	S25/5322	Waitohu GW Zone	26/03/1993
Laurenson Estate	S25/5329	Waitohu GW Zone	26/03/0993

Table A1.3: Greater Wellington's State of Environment groundwater quality monitoring network

Site No.	Site Name	Groundwater Zone
<b>Wairarapa</b>		
S26/0457	Palmer	Ahikouka
S27/0156	O'neale	Battersea
S26/0705	CDC South	Carterton
S26/0824	CDC North	Carterton
S26/0223	Nicholson	East Taratahi
T26/0332	Taratahi Shallow	Fern Hill
S26/0846	Druzianic	Greytown
S26/0467	Fitzgerald Shallow	Hodders
S27/0681	Te Kairanga Shallow	Huangarua Lower Terraces
S27/0268	Barton	Kahutara
S27/0283	Osbourne	Kahutara
S27/0299	Johnson	Lake Domain
S26/0117	Butcher, G	Mangatarere
S27/0389	Dimittina	Martinborough Eastern Terraces
S27/0571	Mtb Golf	Martinborough Eastern Terraces
S27/0522	Duggan	Martinborough Western Terraces
T26/0413	Seymour	Masterton
T26/0430	Trout Hatchery	Masterton
S26/0439	Rogers	Matarawa
S26/0756	Wendon	Middle Ruamahanga
S26/0762	Schaef	Middle Ruamahanga
S27/0202	Croad	Moroa
S27/0594	Warren	Narrows
S27/0585	Mccreary	Onoke
T26/0099	Butcher, M	Opaki
T26/0206	Thornton	Opaki
S26/0568	Denbee	Parkvale
S26/0576	Mcnamara	Parkvale
S27/0607	Findlayson	Pouawha
S27/0495	Bosch	Pukeo
T26/0259	Opaki Water Supply	Rathkeale
S27/0009	Donderman, A	South Featherston
S27/0070	Sth Fstn School	Tauherenikau
S27/0588	Swdc Pirinoa	Taunui
S27/0396	Swdc Martinborough	Tawaha East
S27/0344	George	Tawaha West
S27/0433	Mapuna Atea	Te Hopai
S27/0442	Robinson Transport	Te Hopai
T26/0489	Duffy	Te Ore Ore
T26/0538	Percy	Te Ore Ore
T26/0003	Lenton	Upper Opaki
T26/0087	Biss	Upper Plain
S27/0435	Wairio	Wairio
R25/5233	Op Trust	Waitohu
S25/5322	Edhouse	Waitohu
S26/0299	Graham	West Taratahi
S27/0602	Weatherstone	Whangaehu / Tuhitarata
S27/0614	Sorenson Southern	Whangaehu / Tuhitarata
S27/0615	Sorenson Northern	Whangaehu / Tuhitarata
S27/0136	Sugrue	Woodside
<b>Riversdale</b>		
T27/0063	Acacia Ave	Riversdale GW Zone

Site No.	Site Name	Groundwater Zone
<b>Hutt, Mangaroa and Wainuiomata Valley</b>		
R27/0320	Ibm 1	Lower Hutt
R27/1171	Somes Island	Lower Hutt
R27/1180	Mahoe St/Willoughby St V	Lower Hutt
R27/1182	Seaview Wools	Lower Hutt
R27/1183	Avalon Studios	Lower Hutt
R27/1265	Ibm 2	Lower Hutt
R27/6833	Mangaroa	Mangaroa
R27/1137	South Pacific Tyres	Upper Hutt
R27/6418	Wainuiomata Golf Club	Wainuiomata River
<b>Kapiti Coast</b>		
R25/5100	O'Malley	Coastal
R25/5164	Card	Coastal
R25/5165	Salter	Coastal
R25/5190	Williams	Coastal
R25/5135	Windsor Park	Hautere
S25/5200	Common Property	Hautere
S25/5256	Penray	Hautere
S25/5125	Bettys/Andrews	Otaki
R26/6503	QE Park	Raumati/Paekakariki
R26/6587	Liddle Nurseries	Waikanae
R26/6624	Boffa	Waikanae

## Appendix 2: Groundwater quality variables and analytical methods

Variable	Method Used	Detection Limit
Temperature	Field meter – ExStik DO600 (Extech Instruments), YSI 550A Meters and WTW350i Meters	0.01 °C
Dissolved Oxygen	Field meter – ExStik DO600 (Extech Instruments), YSI 550A Meters and WTW350i Meters	0.01 mg/L
Conductivity	Field meter – ExStik DO600 (Extech Instruments), YSI 550A Meters and WTW350i Meters	0.1 µS/cm
pH	Field meter – ExStik DO600 (Extech Instruments), YSI 550A Meters and WTW350i Meters	0.01 units
pH (lab)	pH meter APHA 4500-H+ B 21st ed. 2005.	0.1 pH units
Electrical Conductivity	Conductivity meter, 25°C APHA 2510 B 21st ed. 2005.	0.1 mS/m, 1 µS/cm
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), Radiometer autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1 mg/L as CaCO <sub>3</sub>
Free carbon dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 21st ed. 2005.	1 mg/L at 25°C
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO <sub>2</sub> D 21st ed. 2005.	1 mg/L at 25°C
Total Dissolved Solids	Filtration (GF/C, 1.2 µm), filtrate dried at 103 - 105 °C, Gravimetric. APHA 2540 C (modified from 180 °C) 21st ed. 2005.	10 mg/L
Dissolved Calcium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.05 mg/L
Dissolved Magnesium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Total Hardness	Calculation: from Dissolved Ca and Dissolved Mg APHA 2340 B 21 <sup>st</sup> ed. 2005.	1 mg/L as CaCO <sub>3</sub>
Dissolved Sodium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Dissolved Potassium	Filtered sample, ICP-MS APHA 3125 B 21st ed. 2005.	0.05 mg/L
Total Ammoniacal-N	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH <sub>4</sub> -N = NH <sub>4</sub> <sup>+</sup> -N + NH <sub>3</sub> -N) APHA 4500-NH <sub>3</sub> F (modified from manual analysis) 21st ed. 2005.	0.01 mg/L
Nitrate-N + Nitrite-N (TON)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO <sub>3</sub> - I (modified) 21 <sup>st</sup> ed. 2005.	0.002 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N.	0.002 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO <sub>3</sub> - I (modified) 21 <sup>st</sup> ed. 2005.	0.002 mg/L
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 mg/L
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 21st ed. 2005.	0.5 mg/L

Variable	Method Used	Detection Limit
Fluoride	Ion selective electrode APHA 4500-F- C 21st ed. 2005.	0.05 mg/L
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 mg/L
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 mg/L
Dissolved Boron	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.005 mg/L
Reactive Silica	Filtered sample. Heteropoly blue colorimetry. Discrete Analyser. APHA 4500-SiO <sub>2</sub> F (modified from flow injection analysis) 21st ed. 2005.	0.1 mg/L as SiO <sub>2</sub>
Total Organic Carbon (TOC)	Catalytic oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 B (modified) 21st ed. 2005.	0.05 mg/L
Dissolved Iron	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.02 mg/L
Dissolved Manganese	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.0005 mg/L
Dissolved Lead	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.0001 mg/L
Dissolved Zinc	Filtered sample. ICP-MS APHA 3125 B 21st ed. 2005.	0.001 mg/L
Total Anions	Calculation: sum of anions as mEq/L [Includes Alk, Cl, NO <sub>x</sub> N & SO <sub>4</sub> ]	0.07 mEq/L
Total Cations	Calculation: sum of cations as mEq/L [Includes Ca, Mg, Na, K, Fe, Mn, Zn & NH <sub>4</sub> N].	0.06 mEq/L
% Difference in Ion Balance	Calculation from Sum of Anions and Cations APHA 1030 E 21st ed. 2005.	0.1 %
Faecal coliforms	APHA 21 <sup>st</sup> Ed. Method 9222 D.	1 cfu/100 mL
<i>E. coli</i>	APHA 21 <sup>st</sup> Ed. Method 9222 G.	1 cfu/100 mL
Dissolved Arsenic	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.001 mg/L
Dissolved Cadmium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00005 mg/L
Dissolved Chromium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 mg/L
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 mg/L
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 mg/L

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