Annual groundwater monitoring report for the Wellington region, 2007/08

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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[1] water supply. Otaki, Waikanae[2], Martinborough, Carterton[3] and Greytown[4] 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 2007 to 30 June 2008 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 annual hydrology monitoring report for 2007/08 (Watts & Gordon 2008).

[1] 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.

[2] In Waikanae, the Kapiti Coast District Council uses groundwater as a backup water supply to its surface water take from the Waikanae River.

[3] Primary supply to Carterton is from surface water.

[4] Primary supply to Greytown is from surface water.

2. Overview of the groundwater monitoring programme

There are three principal groundwater areas in the 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.

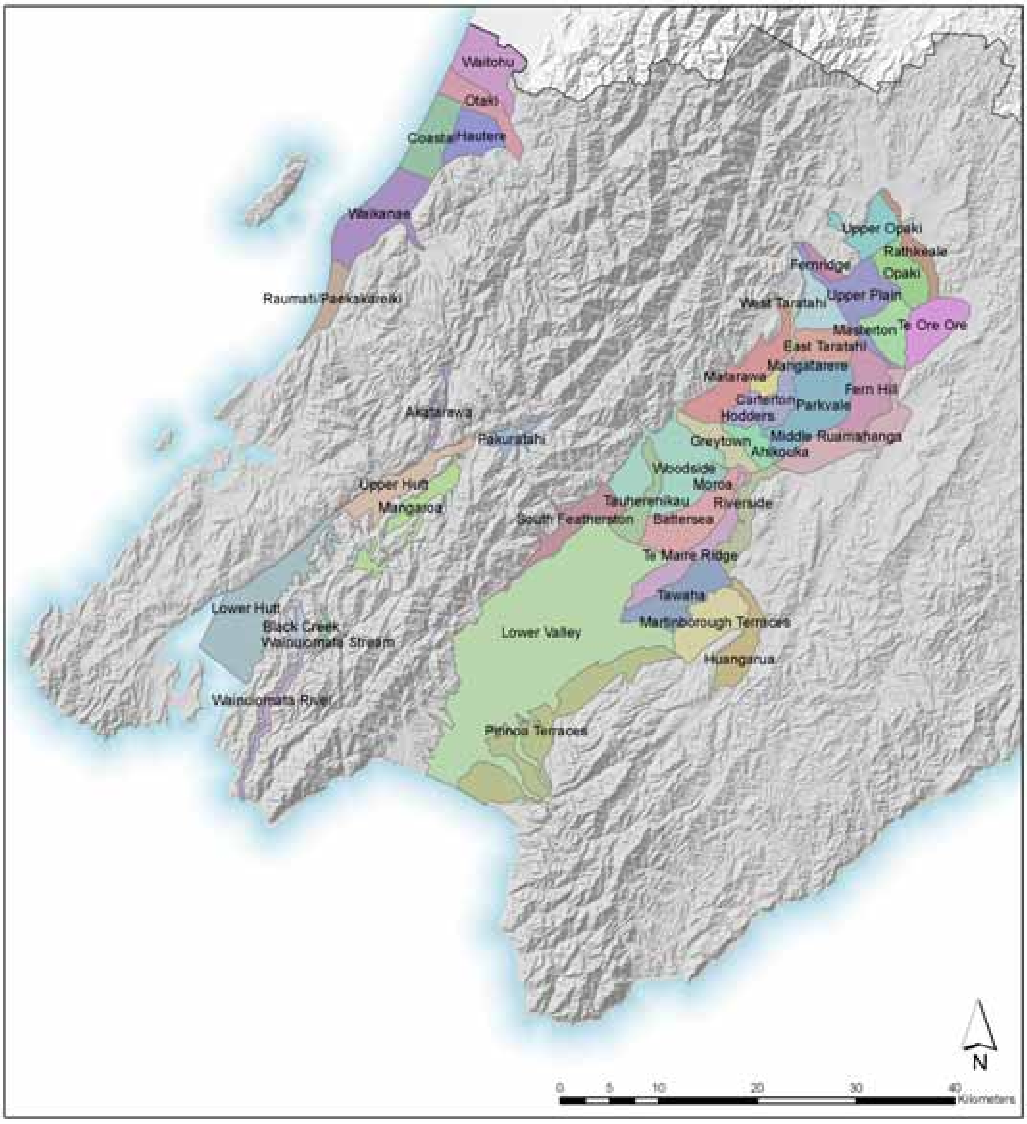

Figure 2.1: Groundwater management zones in the Wellington region

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;
- Determine 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's monitoring network consists of a network of boreholes used for groundwater level and quality monitoring. This network utilises dedicated monitoring boreholes, un-used[5] privately owned boreholes and currently used[6] private boreholes. The groundwater level network currently consists of 60 automatic and 69 manually dipped[7] 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 70 boreholes (Figure 2.3, Appendix 1), sampled quarterly for a wide range of physico-chemical and microbiological variables. Other selected groundwater level and quality monitoring is carried out on a project-specific basis.

A full list of groundwater quality variables monitored, together with details of field and analytical methods, is provided in Appendix 2.

[5] Boreholes previously pumped for supply but no longer utilised for this purpose.
[6] Boreholes that are currently pumped for water supply, this pumping may have short term effects on water level readings.
[7] Boreholes are manually dipped to test depth to groundwater, generally on a four or six week rotation.

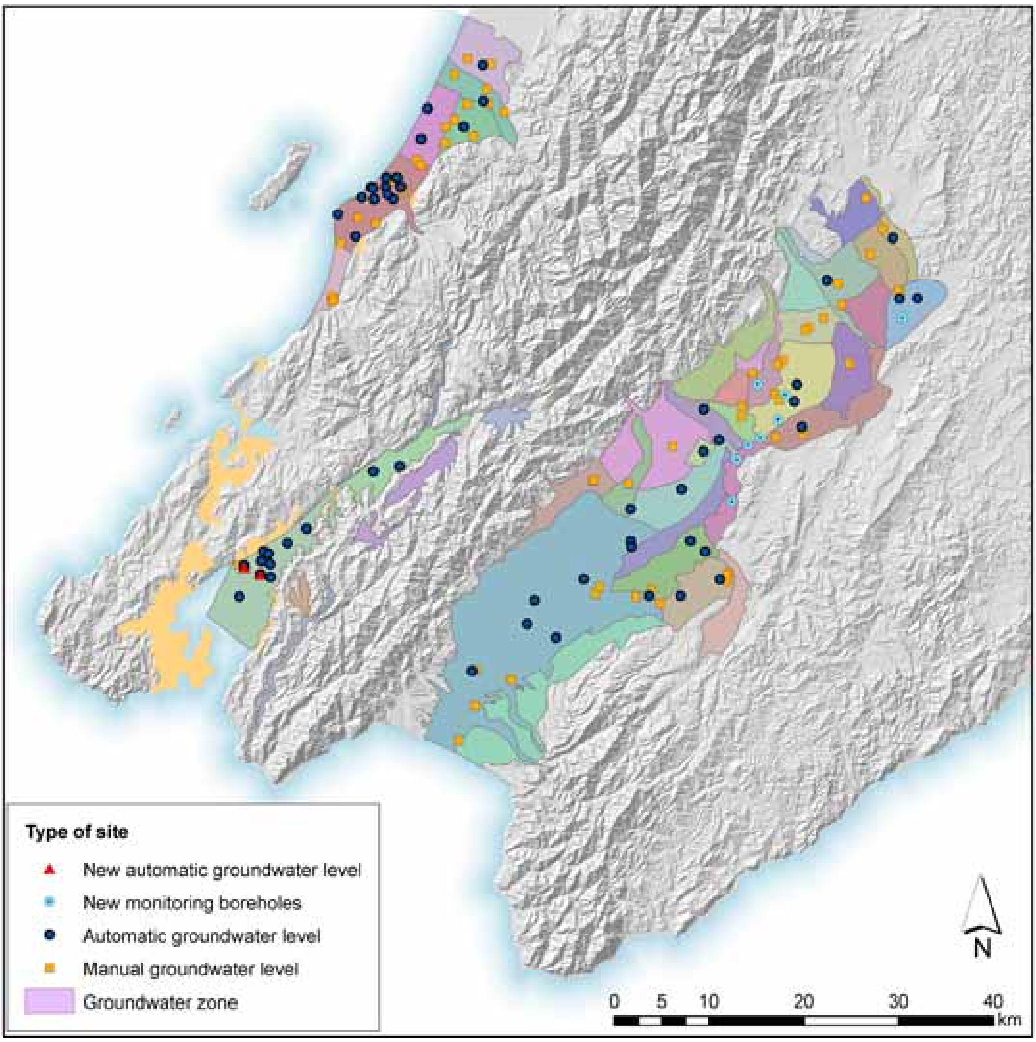

Figure 2.2: Location of groundwater level sites in the Wellington region, monitored over 1 July 2007 to 30 June 2008. New monitoring boreholes on the Petone foreshore are shown, along with boreholes drilled as part of the Wairarapa Groundwater Investigation.

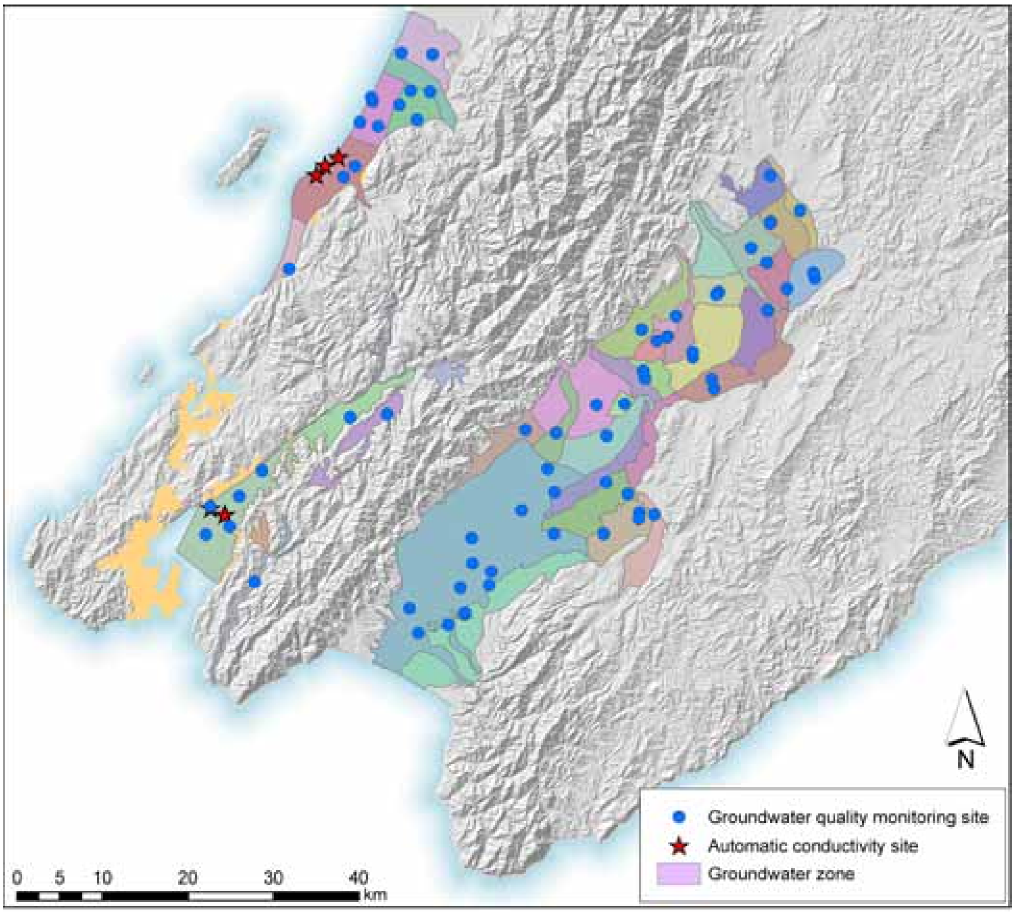

Figure 2.3: Location of routine groundwater quality monitoring sites in the Wellington region. Automated saline intrusion groundwater monitoring sites are also shown.

2.2.1 Changes to the monitoring network in 2007/08

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

- Three new saline intrusion monitoring boreholes constructed in the Lower Hutt Groundwater Zone at Petone in 2006/07 had data logging equipment and telemetry installed during the year. Conductivity and groundwater levels are being monitored at these new locations.

- As part of the Wairarapa groundwater investigation (see Section 3.2), 11 new monitoring boreholes were constructed. These bores were located to provide hydrogeological data in areas with critical 'gaps' in the current monitoring network. Electronic logging equipment will be installed in these wells during 2008/09.

3. Groundwater quantity

3.1 Groundwater levels

Aquifers across the region 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[8]. Examples of rainfall and river flow trends in 2007/08 for Kapiti and the Wairarapa are shown in Figure 3.1 – for further information refer to Watts & Gordon (2008). Figures 3.2 and 3.3 show representative mean monthly groundwater levels against historic data for the main groundwater zones in the region.

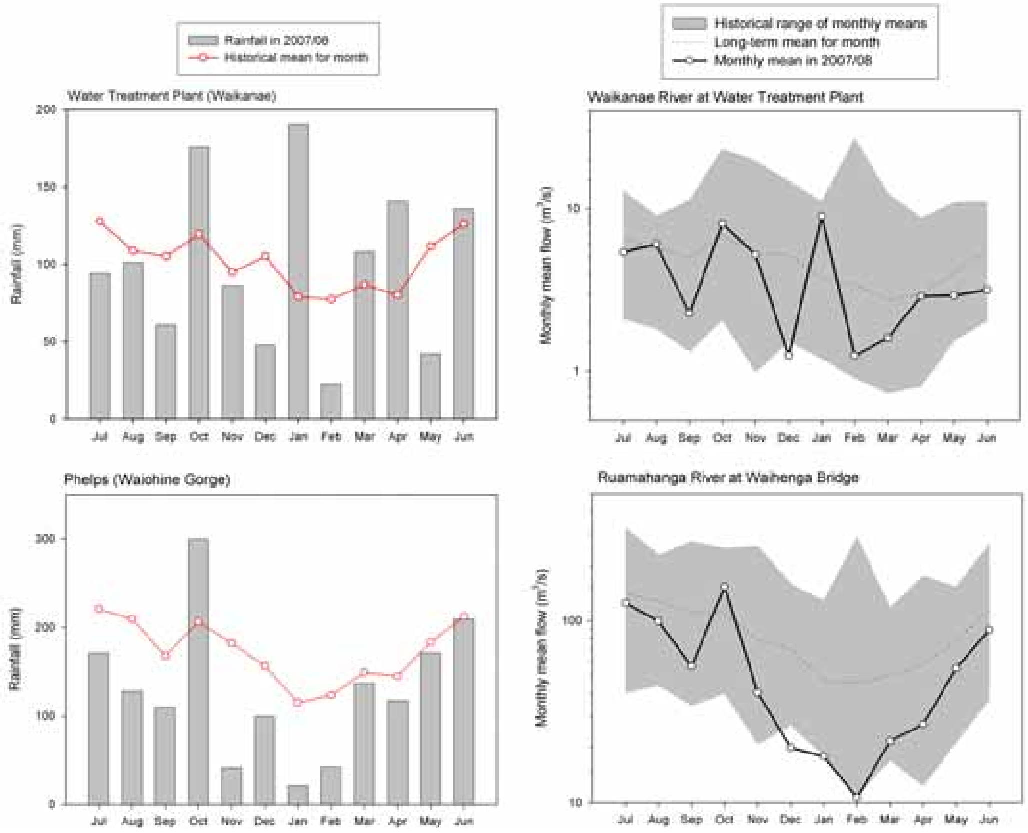

Figure 3.1: Representative monthly rainfall totals for 2007/08 (grey bars) compared to historical mean monthly rainfall (red line) at selected rainfall monitoring locations in the Wellington region. Representative monthly mean river flows for 2007/08 (black line) compared to historical mean monthly rainfall (dotted line) in the Wellington region. Grey area represents the range of historical monthly means.

[8] Deeper aquifers are recharged through the downward percolation of water from shallow aquifers.

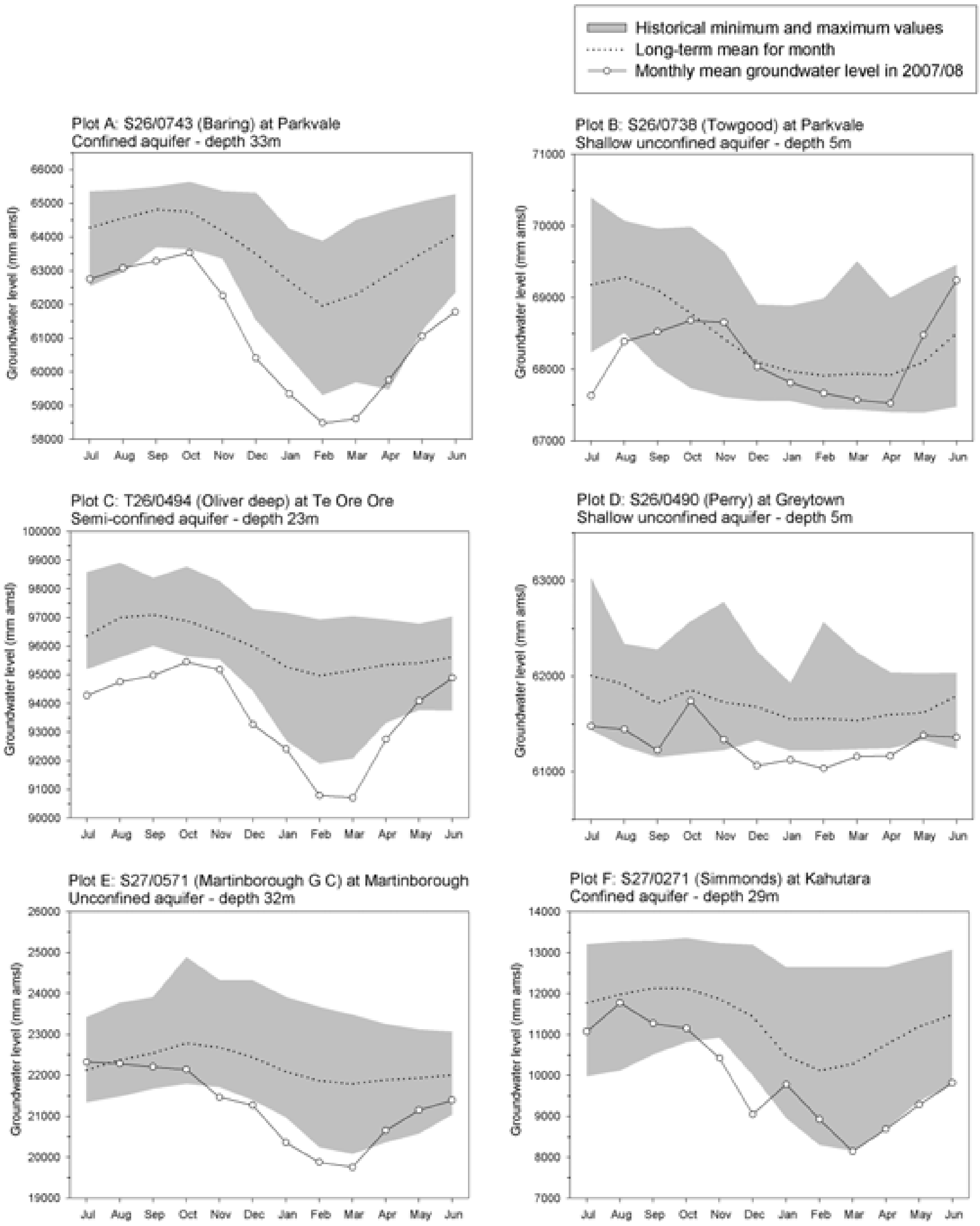

Figure 3.2: Monthly mean groundwater levels for 2007/08 (black line) compared to historical mean monthly groundwater levels (dotted line) at selected sites across the Wairarapa. The grey shaded areas represent the range of historical minimum and maximum monthly mean groundwater levels.

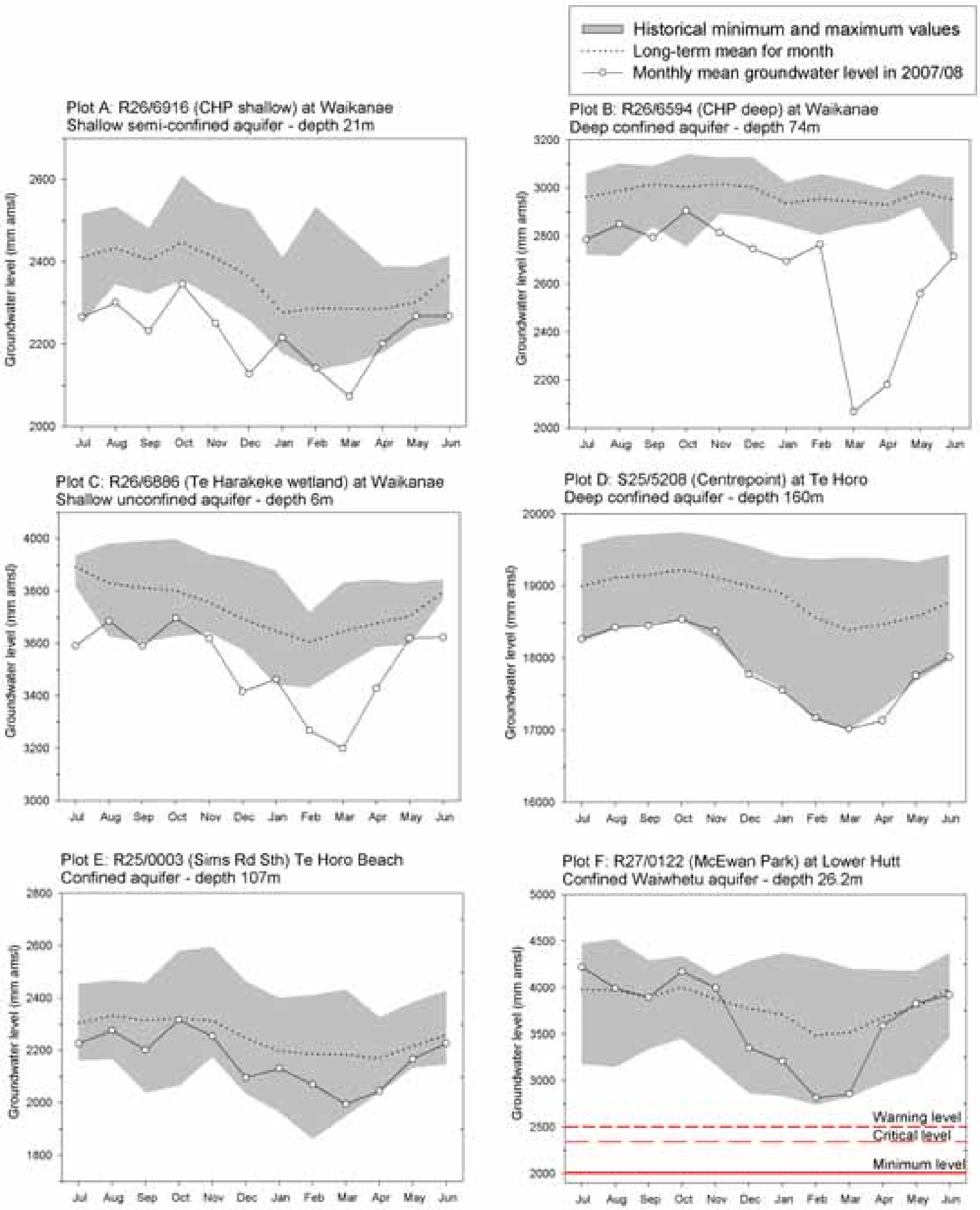

Figure 3.3: Monthly mean groundwater levels for 2007/08 (black line) compared to historical mean monthly groundwater levels (dotted line) at selected sites across the Kapiti Coast and Lower Hutt. The grey shaded areas represent the range of historical minimum and maximum monthly mean groundwater levels.

The winter of 2007 had low rainfall compared to average in most parts of the Wellington region, and this followed on from an extremely dry autumn. The overall effect was significantly below average recharge to aquifers over winter leading to below average groundwater levels during spring 2007 (particularly in the Wairarapa and Kapiti Coast (Figures 3.2 and 3.3).

The pattern of low rainfall continued into late spring and summer as a La Nina episode set in, causing a significant drought in parts of the Wellington region (Watts & Gordon 2008). Rainfall during November 2007 was particularly low – in the Wairarapa it was the driest November in more than 20 years (Watts &

Gordon 2008). By December, river flows were very low for the time of the year throughout the Wellington region (Figure 3.1).

The areas with the lowest rainfall during late spring and summer compared to average were the eastern Wairarapa hills, the Wairarapa plains, the eastern Tararua Range, the Wainuiomata catchment and northern and eastern parts of the Hutt Valley. In these places, rainfall over the period November 2007 to March 2008 was 50-70% of the long-term average. Low river flows were experienced in all the major rivers of the Wellington region. Due to particularly low rainfall in the eastern Tararua Range the Ruamahanga River had its lowest flow since 1985. The drought was broken by rainfall in many places towards the end of March 2008, although in the eastern Wairarapa hills, drought conditions persisted through until May. By June, river flows and soil moisture had returned to about normal levels for the time of the year (Watts & Gordon 2008).

The long dry summer of 2007/08 led to greater demand for groundwater for irrigation and municipal water supply and this was reflected in record-low groundwater levels in many areas. There were a number of reports of shallow boreholes that do not fully penetrate[9] aquifers 'drying up'. The low groundwater levels exacerbated reduced flows in many rivers and spring-fed streams, and reduced water levels in wetlands.

Wetter conditions in May and June 2008 led to a recovery in groundwater levels in shallow unconfined aquifers. However, many of the Wellington region's deeper confined aquifers – which respond to recharge more slowly – still recorded record-low or below average levels during this period.

3.1.1 Wairarapa

Groundwater levels in many confined aquifers in the Wairarapa continued to track at or below long term minima during 2007/08 (Figure 3.2, Plot A and Plot F). Work is continuing with the Wairarapa groundwater modelling exercise (see Section 3.2) to ascertain whether these declining levels are linked to climatic changes and/or groundwater use.

Shallow unconfined rainfall-fed (Figure 3.2, Plot E) and river-fed (Figure 3.2, Plot D) aquifers recorded low groundwater levels throughout much of the year. Groundwater levels in the Te Ore Ore area (Figure 3.2, Plot C) continued the decline of previous years with the annual minimum level approximately 1 m below previous historical levels.

Due to low flow restrictions in several river and stream systems, some riparian[10] groundwater takes in the Wairarapa were limited to 12 hour pumping during the driest times of the year.

Several shallow unconfined aquifers responded to the wetter May and June 2008 (Figure 3.2, Plot B and Plot C).

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[9] Boreholes or wells which have not been drilled to the base of the aquifer.

[10] Riparian groundwater takes are located in close proximity to a surface water body and are inferred to have a connection to that surface water body.

3.1.2 Lower Hutt

There was significant use of the Waiwhetu aquifer during the dry summer for public water supply. This is evident in Figure 3.3 Plot F where the February and March 2008 aquifer groundwater levels were around the long term minimum for this time of year. Management of the water supply take ensured the groundwater levels were maintained above the warning levels for saline intrusion.

3.1.3 Kapiti Coast

The Waikanae borefield was utilised several times during 2007/08 when flows in the Waikanae river were low. The most sustained use was during March 2008; the effect of this can be seen in water levels in the borehole located at Waikanae Christian Holiday Park (Figure 3.3, Plot B).

3.2 Wairarapa groundwater investigation

As reported by McAlister (2007), increasing demand for groundwater irrigation in the Wairarapa over the last decade has led to a need to review the available allocation. A computer model has been developed to assist with this and in 2007/08 modelling was completed for the middle Wairarapa valley. Extensive field operations were carried out throughout the year, including the drilling of 11 monitoring boreholes (Figures 3.4 and 3.5), a seismic geophysics survey, isotope chemistry sampling to determine groundwater age, a springs survey, piezometric survey and reading of meters on water takes. Work will continue next year on modelling the lower and upper parts of the Wairarapa valley.

Figure 3.4: Drilling of a monitoring borehole in the Papawai area of the Wairarapa

Figure 3.5: Two monitoring boreholes constructed to monitor outflows from the Parkvale area. Note the free flowing artesian groundwater flow from one of the wells.

The groundwater model provides a tool which will allow us to test a range of climatic and water abstraction scenarios. The results will contribute to the sustainable management of the groundwater system in the Wairarapa by providing a basis for groundwater allocation provisions in the review of our regional plans, scheduled to begin in 2009/10.

4. Groundwater quality

This section of the report provides a brief overview of the results of groundwater quality monitoring conducted in the Wellington region over 2007/08. 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 the quality of an aquifer system.

4.1 GWSoE monitoring – summary points

As outlined in Section 2.2, routine groundwater quality monitoring involves quarterly sampling of 70 boreholes across the region. With only four sets of sampling results per year, a comprehensive evaluation of all of the data is not undertaken on an annual basis. Comment here is therefore 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.

Other potential sources of groundwater contamination in the Wellington region are from water abstraction at the coast where aquifer systems connect to the ocean. Monitoring of groundwater quality in these areas is critical; over abstraction of groundwater close to the sea may draw sea water inland affecting water quality. Results for 2007/08 show no significant deterioration through the year at any saline intrusion monitoring boreholes in the Lower Hutt or Kapiti aquifers[11].

4.1.1 Nitrate-nitrogen (nitrate)

Elevated (>3 mg/L)[12] nitrate concentrations were recorded in 19 of 70 (27%) GWSoE monitoring boreholes (Figure 4.1). A further six boreholes in the Kapiti Coast and upper Wairarapa valley had nitrate concentrations that were relatively high (7–11.3 mg/L) on at least one occasion, though no results exceeded the Ministry of Health Drinking Water Standards (DWSNZ 2005)

[11] The Wairarapa Valley aquifer system is not thought to have significant connection to the sea – therefore there is no need to report on potential saline intrusion for this system.

[12] 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^3-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).

maximum acceptable value (MAV) of 11.3 mg/L[13]. Generally the elevated nitrate results were seen in areas where groundwater concentrations have historically been elevated. Many of these areas have been the subject of targeted investigations over the last four years (see Section 4.2).

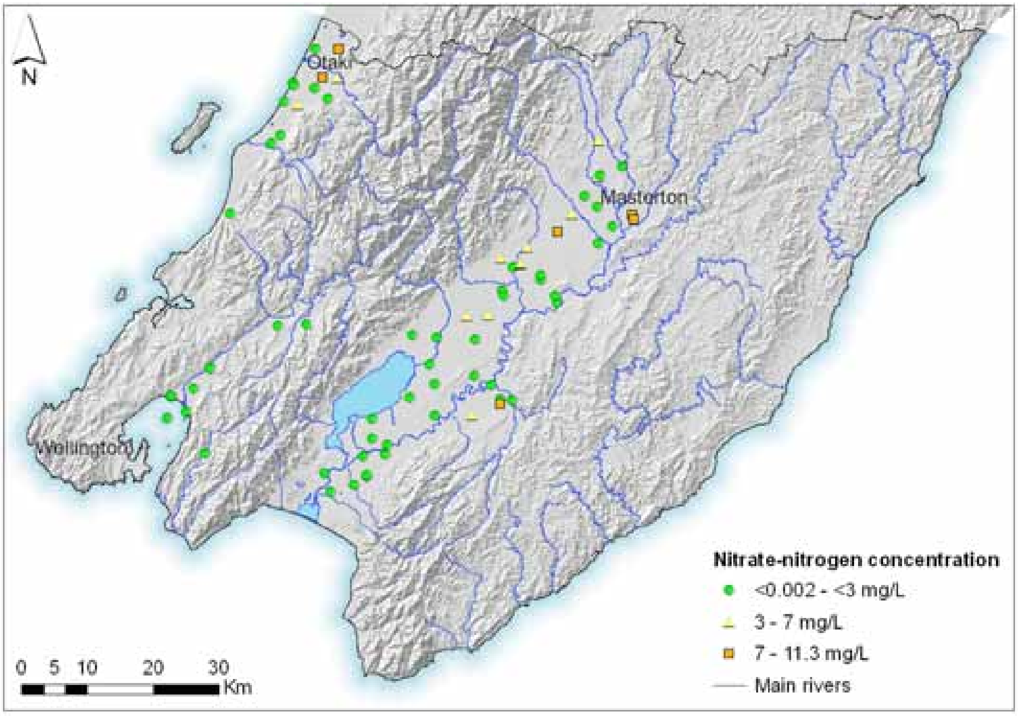

Figure 4.1: Maximum nitrate concentrations recorded in GWSoE monitoring boreholes sampled over 2007/08

4.1.2 *E. coli*

In the DWSNZ (2005), *E. coli* is used as an indicator of contamination of drinking water by faecal material[14]. For drinking water supplies, *E. coli* counts should be <1 cfu/100 mL.

Positive detects for *E. coli* were recorded in 11 boreholes on 13 occasions during four rounds of GWSoE sampling over 2007/08 (Figure 4.2). The highest *E. coli* count recorded was 600 cfu/100mL (R25/ 5164) at Te Horo Beach in the Coastal Zone of Kapiti. Other noteworthy readings were 100 cfu/100 mL in Battersea (S2/0156) and 39 cfu/100 mL (S27/0136) in Woodside.

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[13] One site, located in the lower Wairarapa, recorded a maximum nitrate-nitrogen concentration of 13.7 mg/L but this result is believed to reflect an isolated contamination event and so has been removed from Greater Wellington's database (i.e., not shown in Figure 4.1).

[14] 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

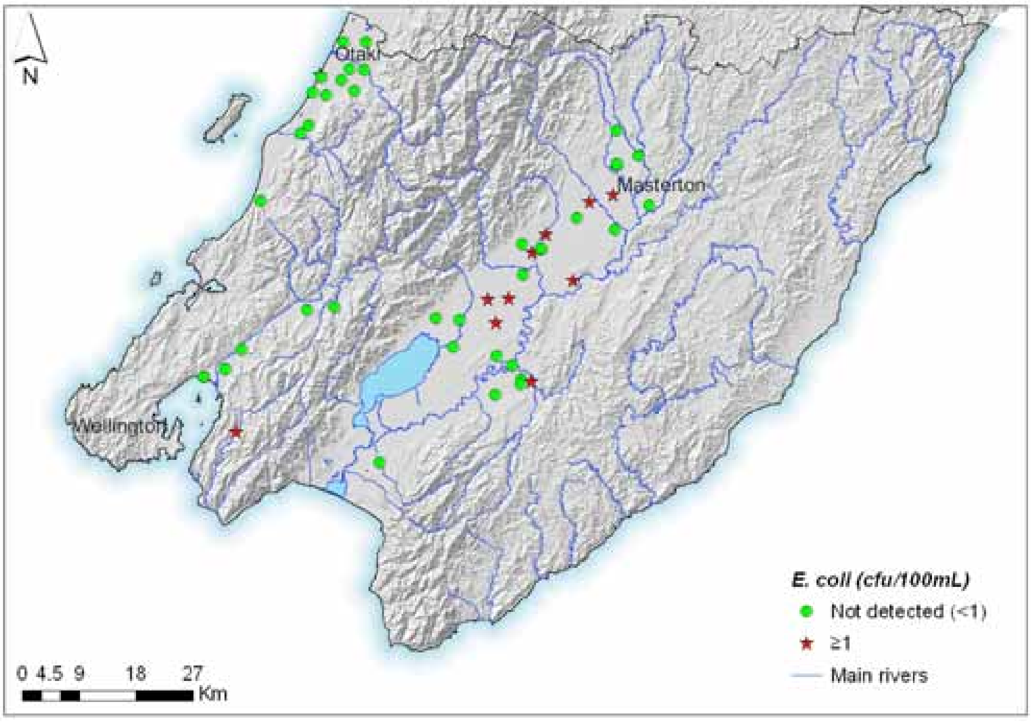

Figure 4.2: Maximum *E. coli* bacteria counts recorded in GWSoE boreholes sampled quarterly over 2007/08. Results from 11 boreholes sampled tested positive for *E. coli*.

4.2 Targeted investigations

In addition to routine monitoring under the GWSoE programme, some specific groundwater quality investigations were also undertaken over 2007/08. These included the monitoring of nitrate concentrations in 18 boreholes on the Te Ore Ore plains in the Wairarapa over November and December 2007 and the continued monitoring of the effects of on-site wastewater system discharges on groundwater quality in the shallow aquifer at Norfolk Road in Carterton.

The results of monitoring investigations at Te Ore Ore and Norfolk Road to date, together with the results from other targeted investigations in the Wairarapa over the last four years highlight that nitrate contamination exists to various degrees (see Tidswell 2008). The greatest contamination is present in shallow groundwater in the intensively farmed Mangatarere (Carterton) and Te Ore Ore areas, with some boreholes exceeding the national drinking water standards for nitrate and *E. coli* bacteria. Contamination is generally higher in the winter months when rainfall is greater, soils are more saturated and groundwater levels higher (Tidswell 2008).

5. Summary

Groundwater quantity in the Wellington region in 2007/08 was dominated by the relatively dry spring 2007 and extremely dry summer 2007/08. These dry conditions significantly reduced recharge to aquifer systems. Reduced recharge combined with groundwater abstraction led to record low groundwater levels at many groundwater monitoring sites across the region. Low groundwater levels exacerbated low flows in interlinked surface water systems. A wetter May and June 2008 produced significant water level recovery in many shallow unconfined aquifers. Many confined aquifers in the region continued to track around long term minima.

Routine groundwater quality monitoring over 2007/08 showed elevated nitrate results and the presence of *E. coli* in a number of boreholes across the region. Elevated results were generally seen in shallow boreholes in areas of intensive farming or where there are a number of wastewater discharges to land. Several targeted investigations in the Wairarapa have indicated that the greatest nitrate contamination is in the Carterton (Mangatarere) and Te Ore Ore areas.

6. References

Close, M.E.; Rosen, M.R.; Smith, V.R. 2001. Fate and transport of nitrates and pesticides in New Zealand's aquifers. In Rosen, M.R. and White P.A., (Eds), *Groundwaters of New Zealand*. New Zealand Hydrological Society, Wellington.

Jones, A.; Baker, T. 2005. *Groundwater monitoring technical report.* Greater Wellington Regional Council, Publication No. GW/RINV-T-05/86.

McAlister, D. 2007: *Annual groundwater monitoring report for the Wellington region 2006/07*. Greater Wellington Regional Council, Publication No. GW/EMI-T-07/222.

Madison, R.J.; Brunett, J.O. 1985. Overview of the occurrence of nitrate in groundwater of the United States. In *National water summary, 1984 – Hydrologic events, selected water quality trends, and groundwater resources.* U.S. Geological Survey – Supply Paper 2275, pp. 93–105.

Ministry of Health. 2005. *Drinking Water Standards for New Zealand 2005*. Ministry of Health, Wellington.

Tidswell, S. 2008: Targeted groundwater quality investigations in the Wairarapa. Greater Wellington Regional Council, Publication No. GW/EMI-T-08/81.

Watts, L.; Gordon, M. 2008. *Annual hydrology monitoring report for the Wellington region, 2007/08.* Greater Wellington Regional Council Publication No. GW/EMI-G-08/159.

Appendix 1: Groundwater monitoring networks

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

Site Name	Site Number	Groundwater Zone	Start Date
Wairarapa Valley			
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
Hutt Valley			
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
TS Tamatoa Deep	R27/7215	Lower Hutt GW Zone	5/02/2008
TS Tamatoa Shallow	R27/7154	Lower Hutt GW Zone	5/02/2008
Kapiti Coast			
Sims Rd Sth	R25/0003	Coastal GW Zone	28/03/1985
Housiaux 4	R26/6881	Coastal GW Zone	22/09/2004
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

Site Name	Site Number	Groundwater Zone	Start Date
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
Wairarapa			
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	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
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
Hodgins	T26/0170	Rathkeale	24/11/1986
Windy Farm /House	S27/0009	South Featherston	01/05/2002
Windy Farm /Deep	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
Masterton District Council	T26/0243	Te Ore Ore	26/09/1988

Site Name	Site No.	Groundwater Zone	Start Date
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	Whangaehu / Tuhitarata	16/04/1982
Carlisle	S27/0148	Woodside	03/08/1983
Hutt Valley			
Nevis St	R27/1223	Lower Hutt GW Zone	03/03/1971
Kapiti Coast			
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 2	R26/6879	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
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 Rangiuru	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
Laurensen 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
Wairarapa		
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

Site No.	Site Name	Groundwater Zone
Hutt, Mangaroa and Wainuiomata Valleys		
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
Kapiti Coast		
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 Imstruments) and YSI 550A meters	0.01 ˚C
Dissolved Oxygen	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A meters	0.01 mg/L
Conductivity	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A meters	0.1 µS/cm
pH	Field meter – ExStik DO600 (Extech Imstruments) and YSI 550A 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 $CaCO_3$
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 r bicarbonates. APHA 4500-CO2 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-CO2 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 21st ed. 2005.	1 mg/L as $CaCO_3$
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. (NH4-N = NH4+-N + NH3-N) APHA 4500-NH3 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-NO3 - I (modified) 21sted. 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-NO3 - I (modified) 21st ed. 2005.	0.002 mg/L
Dissolved Reactive Phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st ed. 2005.	0.004 mg/L
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 21st ed. 2005.	0.5 mg/L
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 mg/L
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

Variable	Method Used	Detection Limit
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-SiO2 F (modified from flow injection analysis) 21st ed. 2005.	0.1 mg/L as SiO_2
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 mEquiv/L [Includes Alk, Cl, NOxN & SO4]	0.07 mEquiv/L
Total Cations	Calculation: sum of cations as mEquiv/L [Includes Ca, Mg, Na, K, Fe, Mn, Zn & NH4N].	0.06 mEquiv/L
% Difference in Ion Balance	Calculation from Sum of Anions and Cations APHA 1030 E 21st ed. 2005.	0.1 %
Faecal coliforms	APHA 21st Ed. Method 9222 D.	1 cfu/100 mL
E. coli	APHA 21st Ed. Method 9222 G.	1 cfu/100 mL