

Groundwater Quality State of the Environment monitoring programme

Annual data report, 2014/15

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GW/ESCI-T-15/150
ISBN:978-1-927217-87-0 (online)

November 2015

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The report may be cited as:

Tidswell S. 2015. *Groundwater Quality State of the Environment monitoring programme, Annual data report, 2014/15*. Greater Wellington Regional Council, Publication No. GW/ESCI-T-15/150, Wellington.

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1. Introduction

This report summarises the results from Greater Wellington Regional Council's (GWRC) Groundwater Quality State of the Environment (GQSoE) monitoring programme for the period 1 July 2014 to 30 June 2015 inclusive. The GQSoE programme incorporates quarterly monitoring of water quality in 71 bores across the Wellington Region.

Reports containing detailed analyses of long-term trends are produced approximately every five years (see Jones & Baker 2005, Tidswell et al 2012).

2. Overview of GQSoE monitoring programme

Groundwater quality has been routinely monitored in the western half of the Wellington Region (Kapiti Coast and Hutt Valley) since 1994 and in the Wairarapa since 1997. Up until 2003, this monitoring was effectively conducted under two separate programmes, with some differences in the suite of water quality variables and analytical methods. From late 2003, management practices were aligned to provide consistency in sampling methods, sampling frequency (increased from six-monthly to quarterly), analysis and reporting. At this time, a number of changes were also made to the location of monitoring sites, the range of variables monitored and the methods of analysis to improve the representativeness and quality of the information collected (see Jones & Baker 2005 and Tidswell et al 2012) for more details.

2.1 Monitoring objectives

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

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

2.2 Monitoring network

The existing GQSoE monitoring network consists of 71 bores (Figure 2.1, Appendix 1). During the 2014/15 year, only 68 bores were sampled. Three bores could not be used for the reasons shown below:

- Bore S25/5256 was purchased by Transit for the Peka Peka to Otaki Expressway. GWRC have not been able to retain power at the site to use the pump and continue sampling.
- Bore R27/1137 was decommissioned in September 2010. However, this bore has been reinstated by Wellington Water and a groundwater quality sample collected as part of the September 2015 sampling round.
- Bore S27/0614 Sorenson South was decommissioned due to borehole collapse around March 2014. A bore drilled in place of bore S27/0614 could not be sampled during the 2014/15 sampling period due to bore development issues.

Further to this, GQSoE samples could be obtained once during the 2014/15 period from two bores for the reasons below:

- Bore S26/0756 was sampled in September 2014. However, repairs to the bore and bore headworks did not include a sample tap. Subsequently, water samples have not been collected since as the cost of installing a sampling tap is cost-prohibitive at this stage. Inclusion of this bore in the GQSoE network will be evaluated as part of the network review later in the year.
- Bore R27/1180 has not been able to be sampled since December 2011 due to prolific growth of iron bacteria in the bore. However, over the 2014/15 period, the bore was cleaned and has been pumping since that time. Groundwater quality samples have been collected since March 2015.

Water quality data from the above two bores was included in data analysis for the 2014/15 period.

Faecal indicator bacteria¹ are only tested for in 44 of the 71 GQSoE bores. As sampling could not be conducted at bore R27/1137, only 43 bores were tested for the presence of faecal indicator bacteria during 2014/15.

With the exception of a single bore at Riversdale on the eastern Wairarapa Coast, all bores are located in one of the three principal groundwater management areas in the Wellington Region; the Kapiti Coast, Lower Hutt Valley or the Wairarapa Valley (see Jones & Baker 2005 and Hughes & Gyopari 2011 for a description of groundwater management areas in the Wellington Region).

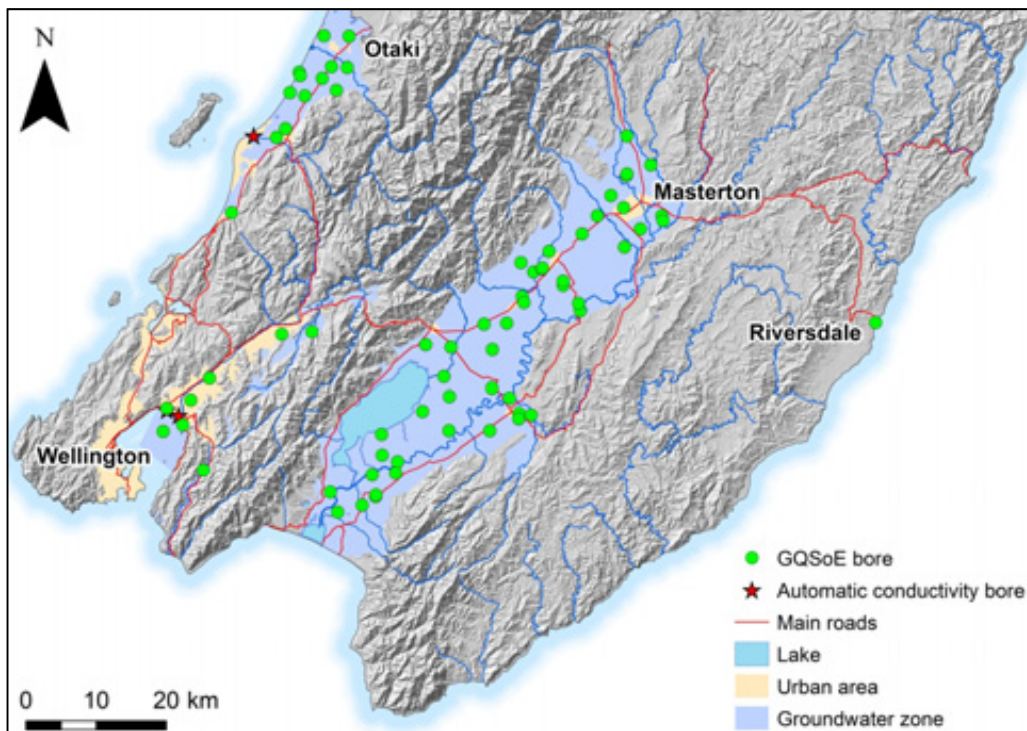


Figure 2.1: Location of groundwater quality monitoring sites in the Wellington Region. Automated saline intrusion (conductivity) groundwater monitoring sites are also shown (red stars).

¹ *Escherichia coli* and faecal coliforms are only tested for in GQSoE bores that are used for potable water supply.

2.3 Monitoring variables

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

Groundwater quality is assessed by measuring 31 different variables including pH, conductivity, turbidity, faecal indicator bacteria, total organic carbon, dissolved nutrients and major ions. A full list of the variables measured and the analytical methods used are provided in Appendix 2.

3. Physico-chemical and microbiological water quality

3.1 Approach to analysis

This section provides a brief overview of groundwater quality in the 2014/15 year. As the sampling regime only provides four sets of results per bore per year, a comprehensive evaluation of all the different variables is not undertaken on an annual basis. Instead, the analysis in this report focuses on two key indicators of groundwater contamination arising from landuse intensification and/or on-site wastewater disposal systems; nitrate-nitrogen (nitrate) and *Escherichia coli* (*E. coli*) bacteria.

Details of the analytical methods used are provided in Appendix 2 (Table A2.2). Summary statistics were calculated using Microsoft Excel Professional Plus 2010 and full data summaries are provided in Appendix 3. Data with values less than the laboratory's analytical detection limit were assigned a value of half their respective detection limit. Raw data is provided in Appendix 4.

3.2 Results

3.2.1 Nitrate

Median nitrate concentrations were low ($<3\text{mg/L}^2$) in most of the 67 bores monitored during 2014/15. Eight of the 68 (11.7%) bores had elevated (3-7 mg/L) concentrations of nitrate (Figure 3.1). A further four (5.9%) bores in Kapiti and upper Wairarapa Valley had median nitrate concentrations in the relatively high range (7-11.3 mg/L).

Two bores had maximum nitrate concentrations above the Ministry of Health Drinking-water Standards (DWSNZ) 2008 maximum acceptable value (MAV) concentration of 11.3 mg/L on one individual sampling occasion each. Bore T26/0489 (54 metres deep) had a maximum concentration of 11.4 mg/L detected in September 2014 and bore S26/0223 (9.92 meters deep) had a maximum concentration of 11.8 mg/L detected in December 2014 (Appendix 4). Both bores are located in upper Wairarapa. No maximum nitrate concentrations were above the DWSNZ MAV in any other bore.

² Groundwater nitrate nitrogen (nitrate) concentrations were also evaluated in terms of likely human influence since groundwater in New Zealand rarely has nitrate concentration above 1 mg/L naturally (Close et al. 2001). A threshold of 3 mg/L was adopted as a means of defining nitrate contamination from anthropogenic sources (Close et al. 2001). This threshold has been used by Greater Wellington in previous reporting (Tidswell et al 2012) and 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. Reference to "elevated" nitrate concentrations indicates the concentrations are above 3 mg/L; an additional 'highly elevated' threshold was arbitrarily set at >7 mg/L, approximately mid-way between the elevated threshold and DWSNZ MAV of 11.3 mg/L.

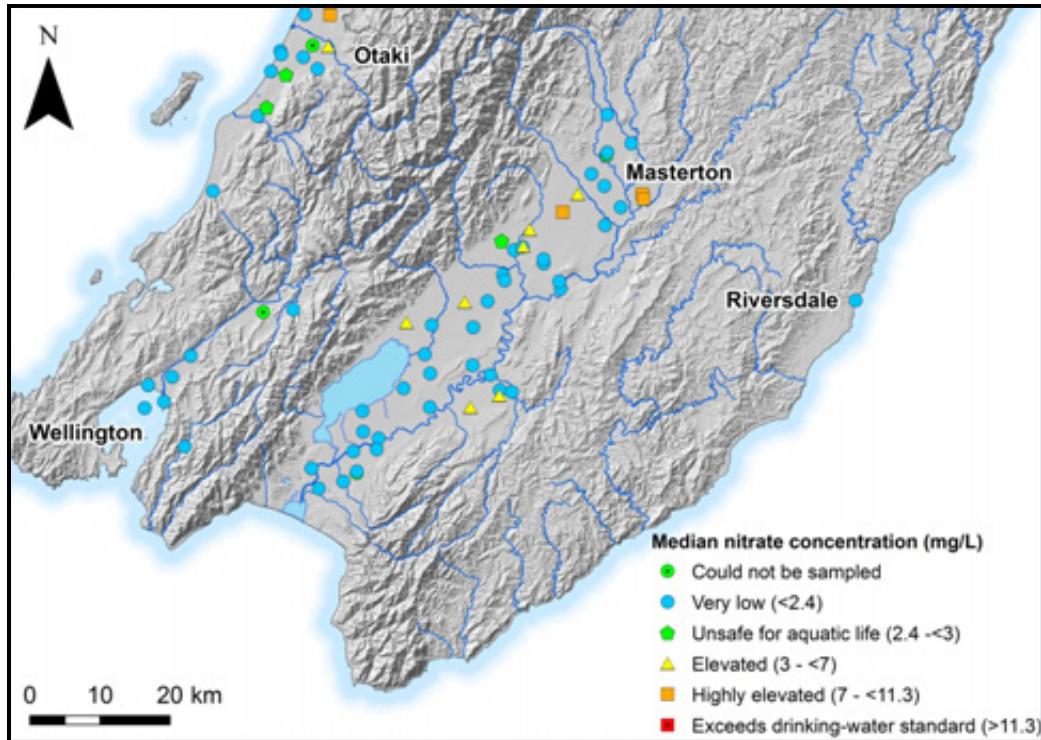


Figure 3.1: 2014/15 median nitrate concentrations in GQSoE monitoring bores

Overall, nitrate contamination was found in bores where previous sampling has detected elevated nitrate concentrations, in areas of intensive agriculture (Wairarapa) and horticulture (Kapiti Coast). The wide-ranging depth of bores with elevated nitrate concentrations (<5 m to 54 m) suggests that nitrate contamination is not limited to shallow unconfined aquifers but is able to migrate into deeper aquifer systems³.

Groundwater discharges to a number of surface water bodies throughout the region and there is the potential that groundwater discharge high in nitrate could contribute to the decline of surface water quality. The ANZECC (2000) guidelines are commonly used to assess physico-chemical aspects of surface water quality in rivers and streams. Median nitrate concentrations were above the ANZECC (2000) trigger value for lowland ecosystems (≤ 0.444 mg/L) in 37 of the 68 (54.4%) bores. Of these, 16 (23.5%) recorded median concentrations above the Hickey (2013) threshold for aquatic toxicity (≤ 2.4 mg/L)⁴.

3.2.2 *E. coli*

The DWSNZ uses *E. coli* as an indicator⁵ of faecal contamination in drinking water. For drinking water supplies, *E. coli* counts should be <1 cfu/100mL.

E. coli was not detected (ie, <1 cfu/100mL) in 33 of the 43 (76.7%) bores monitored.

³ This is particularly evident in recharge areas, with elevated nitrate concentrations not commonly found in deeper confined aquifers.

⁴ This (median) value replaces the former threshold of 1.7 mg/L (Hickey & Martin 2009) and is a recommended replacement value for the ANZECC (2000) toxicity threshold value of 7.2 mg/L.

⁵ 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.

E. coli was detected (ie, ≥ 1 cfu/100mL) on one or more occasions in 10 of the 43 (23.3%) bores tested (Figure 3.2). The highest *E. coli* count was 3000 cfu/100mL in bore R25/5164 at Te Horo Beach. Te Horo Beach is a small settlement reliant on onsite wastewater treatment systems for effluent disposal. Previous studies involving dye tracer tests have confirmed that groundwater at Te Horo Beach is able to move from wastewater treatment systems into nearby bores relatively quickly (Hughes 1998). It is possible that the microbial contamination in bore R25/5164 is due to the bore's proximity to a nearby wastewater treatment system. This bore is not used as a potable drinking water supply.

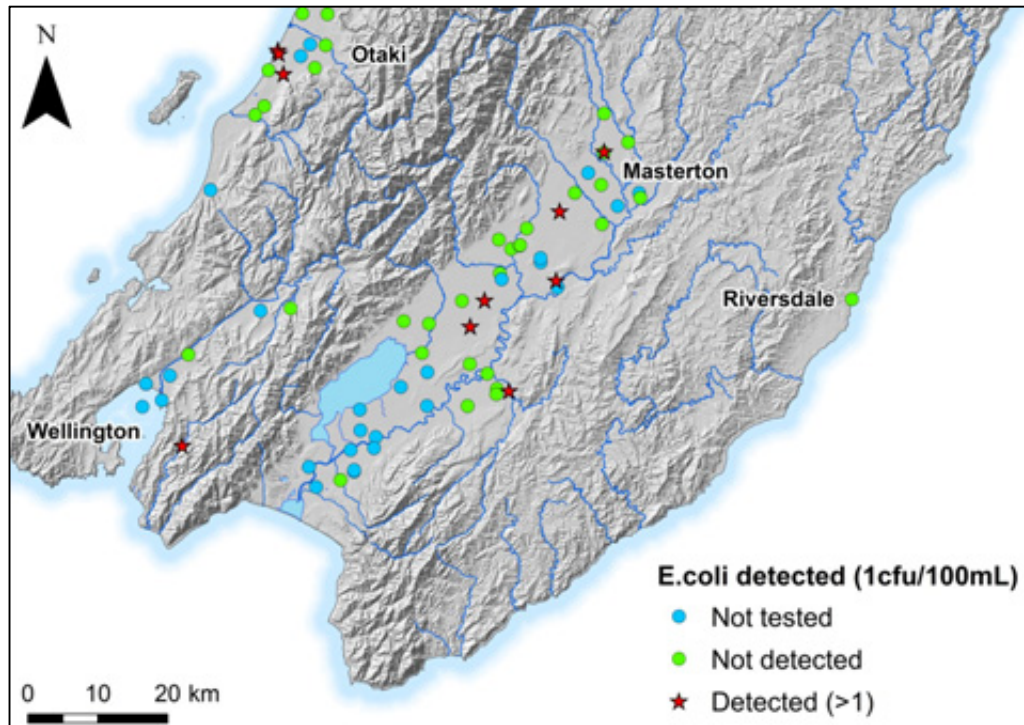


Figure 3.2: Detection of *E. coli* bacteria in GQSoE monitoring bores in 2014/15

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Acknowledgements

I would like to thank Philippa Crisp and Penny Fairbrother for their assistance with this report, and to Wendy Purdon, Braden Crocker, Kasey Pitt and Sam Warren for assisting with GQSoE sampling.

Appendix 1: GQSoE monitoring sites

Site number	Site name	X coordinates	Y coordinates	Groundwater zone	Category
Kapiti Coast					
R25/5100	O'Malley	1774552.15	5479451.35	Te Horo	Category B
R25/5135	Windsor Park	1779152.45	5481483.39	Te Horo	Category C
R25/5164	Card	1775873.28	5482367.50	Te Horo	Category B
R25/5165	Salter	1776019.28	5481886.47	Te Horo	Category B
R25/5190	Williams	1776678.23	5478988.27	Te Horo	Category B
R25/5233	Otaki Porirua Trust	1779397.56	5487564.84	Otaki	Category A
R26/6503	Queen Elizabeth Park	1766253.09	5462295.15	Raumati	Category B
R26/6587	Liddle	1772633.83	5473057.09	Waikanae	Category A
R26/6624	Boffa	1773932.93	5474297.10	Waikanae	Category B
S25/5125	Betty Partnership	1782733.73	5483013.44	Otaki	Category A
S25/5200	Common Property	1781182.52	5479785.21	Te Horo	Category C
S25/5256	Penray	1780490.58	5483153.49	Te Horo	Category C
S25/5322	Edhouse	1782982.85	5487485.83	Otaki	Category C
Hutt, Mangaroa and Wainuiomata Valley					
R27/0320	IBM 1	1756996.50	5434507.51	Hutt Valley	Category B
R27/1137	South Pacific Tyres	1773406.32	5444956.34	Hutt Valley	Category A
R27/1171	Somes Island	1756493.07	5431226.71	Hutt Valley	Category B
R27/1180	Mahoe/Willoughby St	1760435.48	5435698.05	Hutt Valley	Category B
R27/1182	Seaview Wools	1759274.04	5432161.32	Hutt Valley	Category B
R27/1183	Television New Zealand	1763083.77	5438690.64	Hutt Valley	Category A
R27/1265	IBM 2	1756997.50	5434515.51	Hutt Valley	Category B
R27/6418	Wainuiomata Golf Club	1762217.86	5425695.18	Wainuiomata	Unknown
R27/6833	Mangaroa School	1777716.35	5445323.81	Mangaroa	Unknown
Wairapa Valley					
S26/0117	Butcher, G	1811483.15	5456780.11	Mangatarere	Category A
S26/0223	Nicholson	1816203.19	5459284.79	Taratahi	Category B
S26/0299	Graham	1818354.91	5461869.91	Taratahi	Category B
S26/0439	Rogers	1807492.42	5455180.48	Mangatarere	Category B
S26/0457	Palmer Berry Fruits	1807656.62	5450330.89	Waiohine	Category A
S26/0467	Fitzgerald	1809272.40	5453850.06	Mangatarere	Category A
S26/0568	Denbee	1813486.57	5451921.15	Parkvale	Category B
S26/0576	Mcnamara	1813461.67	5452534.23	Parkvale	Category B
S26/0705	Carterton District Council South	1810471.61	5454278.93	Mangatarere	Category B
S26/0756	Stevenson	1815919.19	5448296.24	Middle Ruamahanga	Category A
S26/0762	Schaefer	1815702.37	5449348.42	Middle Ruamahanga	Category A
S26/0824	Carterton District Council North	1810546.63	5454380.93	Mangatarere	Category B
S26/0846	Druzianic	1807902.50	5449491.76	Waiohine	Category A
S27/0009	Dondertman	1793895.42	5443481.45	Tauherenikau	Category B
S27/0070	South Featherston School	1797507.54	5443110.86	Tauherenikau	Category B
S27/0136	Sugrue	1802217.44	5446389.36	Tauherenikau	Category B
S27/0156	O'Neale	1803402.88	5442775.85	Tauherenikau	Category B
S27/0202	Croad	1805460.73	5446519.85	Tauherenikau	Category B
S27/0268	Barton	1793452.70	5434055.07	Lake	Category B
S27/0283	Osborne	1797276.24	5436168.48	Tauherenikau	Category B
S27/0299	Johnson	1796503.73	5438935.77	Tauherenikau	Category A
S27/0344	George	1803347.81	5437340.43	Lower Ruamahanga	Category A
S27/0389	Dimattina	1807205.35	5433792.40	Martinborough	Category C
S27/0396	SWDC Martinborough	1805858.70	5435961.84	Lower Ruamahanga	Category A
S27/0433	Mapuna Atea	1787692.45	5427838.97	Lake	Category B
S27/0435	Wairio	1787608.01	5430805.03	Lake	Category B
S27/0442	Robinson Transport	1789891.27	5426883.54	Lake	Category B
S27/0495	Bosch	1797227.31	5431330.26	Lower Ruamahanga	Category A
S27/0522	Duggan	1803031.58	5431324.10	Martinborough	Category C
S27/0571	Martinborough Golf Club	1807158.18	5433014.36	Martinborough	Category C
S27/0585	McCreary	1780320.53	5422598.32	Onoke	Category C
S27/0588	SWDC Piriona	1784844.06	5420713.48	Onoke	Category A
S27/0594	Warren	1781350.93	5419721.16	Onoke	Category C
S27/0602	Weatherstone	1789625.95	5425301.57	Lake	Category B

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

Appendix 2: Monitoring variables and analytical methods

Groundwater samples are collected quarterly by trained GWRC staff using nationally accepted protocols (Ministry for the Environment 2006). This involves purging the bore for a predetermined amount of time to remove any standing water and monitoring the pumped water continuously until field measurements (eg conductivity) stabilise. Field measurements (temperature, conductivity, pH and dissolved oxygen) are taken using field meters which are calibrated on the day of sampling.

Water samples are stored on ice upon collection and transported to an external laboratory within 24 hours of sampling. RJ Hill Laboratories in Hamilton analysed the samples for the variables listed in Table A2.1

The rationale for variables monitored is detailed in Table A2.1 and analytical methods are summarised in Table A2.2.

Table A2.1. Rationale for inclusion in GQSoE sampling regime

Test type	Variable	Rationale for inclusion
Bacteria	Faecal coliforms <i>E. coli</i>	Faecal coliforms and <i>E. coli</i> can indicate pollution due to faecal matter and the presence of potentially harmful pathogens in groundwater. Ministry for the Environment uses <i>E. coli</i> as an indicator of ground water quality.
Major ions	Dissolved sodium Dissolved potassium Dissolved calcium Dissolved magnesium Chloride Sulphate Total alkalinity	Concentrations of major ions can give an indication of the chemical composition of the water, the origins of groundwater, water residence time in the aquifer and extent of rock/water interaction. Concentrations of major ions can also be indicative of groundwater contamination from industrial, agricultural and domestic sources.
Nutrients	Total ammoniacal nitrogen Nitrite-nitrate nitrogen (NNN) Nitrate nitrogen Nitrite nitrogen Dissolved reactive phosphorus	Dissolved concentrations of nutrients can indicate impact from anthropogenic activity such as intensive land use. Nitrate nitrogen represents the oxidised form of nitrogen. Elevated concentrations of nitrate nitrogen can have an adverse effect on human health and can be harmful to biota. Total ammoniacal nitrogen usually exists under oxygen-poor conditions and represents the reduced form of nitrogen. Therefore, can be used as an indicator of contamination in the absence of nitrate nitrogen. The ANZECC guidelines (2000) state trigger values for the direct toxicity to biota.

Table A2.1 cont. Rationale for inclusion in GQSoE sampling regime

Chemical tests	Variable	Rationale for inclusion in sampling regime
Metals	Dissolved iron	Trace metals are usually present in groundwater at low concentrations. Elevated concentrations of trace metals can suggest contamination of groundwater. Elevated concentrations of dissolved lead and manganese can have an adverse effect on human health.
	Dissolved manganese	
	Dissolved lead	
	Dissolved zinc	
Trace elements	Bromide	Bromide naturally occurs in water but can suggest contamination from wastewater and agricultural run off. Elevated concentrations of dissolved boron can have an adverse effect on human health and the DWSNZ (2005) MAV for fluoride is set to protect against potential dental fluorosis.
	Fluoride	
	Dissolved boron	
Other	pH	Water with a low pH can have a high plumbosolvency. Measured in the field to identify when the bore is purged and sample can be collected.
	Electrical conductivity	Electrical conductivity can provide a measure of total dissolved solids. Measured in the field to identify when the bore is purged and sample can be collected.
	Dissolved oxygen	Dissolved oxygen can indicate whether groundwater is under reduced or oxidised conditions. Measured in the field to identify when the bore is purged and sample can be collected.
	Dissolved reactive silica	Can help interpret the extent of rock/water interaction
	Total organic carbon (TOC)	Can indicate the presence of organic matter (either from wastewater or natural sources) in groundwater.
Calculations	Total dissolved solids (TDS)	Can indicate the extent of rock/water interaction.
	Free carbon dioxide (CO ₂)	Can indicate the extent of rock/water interaction.
	Bicarbonate (H ₂ CO ₃)	Can indicate the extent of rock/water interaction.
	Total hardness	Can indicate the extent of rock/water interaction.
	Total anions	Sum of all anions
	Total cations	Sum of all cations
	% Difference in ion balance	Difference between the sum of all anions and the sum of all cations. Can be used as a measure of analytical accuracy of water quality data. Value should be 0% but generally a difference of <5% is considered acceptable.

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

Table A2.2. Analytical methods

Variable	Method Used	Detection Limit
Temperature	Field meter – WTW350i and YSI Professional Plus Meters	0.01 °C
Dissolved oxygen	Field meter – WTW350i and YSI Professional Plus Meters	0.01 mg/L
Electrical conductivity	Field meter – WTW350i and YSI Professional Plus Meters	0.1 µS/cm
pH	Field meter – WTW350i and YSI Professional Plus Meters	0.01 units
pH (lab)	pH meter APHA 4500-H+ B 22 st ed. 2012.	0.1 pH units
Total alkalinity	Titration to pH 4.5 (M-alkalinity), Radiometer autotitrator. APHA 2320 B (Modified for alk <20) 22 st ed. 2012.	1 mg/L as CaCO ₃
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 22 st ed. 2012.	1 mg/L at 25°C
Free carbon dioxide	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO ₂ D 22 st ed. 2012.	1.0 mg/L at 25°C
Total hardness	Calculation from calcium and magnesium. APHA 2340 B 22 st ed. 2012.	1.0 mg/L CaCO ₃
Electrical conductivity (lab)	Conductivity meter, 25°C APHA 2510 B 22 st ed. 2012.	0.1 mS/m, 1 µS/cm
Total dissolved solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 – 105°C used rather than 180 ± 2°C) 22 st ed. 2012.	10 mg/L
Dissolved boron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.005 mg/L
Dissolved calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.05 mg/L
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.02 mg/L
Dissolved Lead	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.0001 mg/L
Dissolved magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.02 mg/L
Dissolved manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.0005 mg/L
Dissolved potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.05 mg/L
Dissolved sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.02 mg/L
Dissolved zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22 st ed. 2012.	0.001 mg/L
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 22 st ed. 2012.	0.05 mg/L
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500-Cl- E (modified from continuous-flow analysis) 22 st ed. 2012.	0.5 mg/L
Fluoride	Ion selective electrode APHA 4500-F- C 22 st ed. 2012.	0.05 mg/L
Total ammoniacal nitrogen	Filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH ₄ -N = NH ₄ ⁺ -N + NH ₃ -N) APHA 4500-NH ₃ F (modified from manual analysis) 22 st ed. 2012.	0.01 mg/L
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO ₃ - I (modified) 22 st ed. 2012.	0.002 mg/L
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - Nitrite-N. In-House.	0.001 mg/L
Nitrate-N + Nitrite-N (NNN)	Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO ₃ - I (modified) 22 st ed. 2012.	0.002 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 22 st ed. 2012.	0.004 mg/L
Reactive silica	Filtered sample. Heteropoly blue colorimetry. Discrete Analyser. APHA 4500-SiO ₂ F (modified from flow injection analysis) 22 st ed. 2012.	0.1 mg/L as SiO ₂
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22 st ed. 2012.	0.5 mg/L
Total organic carbon (TOC)	Supercritical persulphate oxidation, IR detection, for Total C. Acidification, purging for Total Inorganic C. TOC = TC -TIC. APHA 5310 C (modified) 22 st ed. 2012.	0.05 mg/L
Total anions	Calculation: sum of anions as mEq/L [Includes Alk, Cl, NO _x N, F, DRP & SO ₄]. APHA 1030 E 22 nd ed. 2012.	0.07 mEq/L
Total cations	Calculation: sum of cations as mEq/L [Includes pH (H ⁺), Ca, Mg, Na, K, Fe, Mn, Zn & NH ₄ N]. APHA 1030 E 22 nd ed. 2012.	0.06 mEq/L
% Difference in Ion Balance	Calculation from Sum of Anions and Cations. Please note: The result reported for the '% Difference in Ion Balance' is an absolute difference between the 'Sum of Anions' and 'Sum of Cations' based on the formula	0.1 %

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

Appendix 3: Tabulated statistical data

Site	X	Y	<i>E.coli</i> detected	No. of <i>E.coli</i> samples	Median nitrate	No. of nitrate samples
R25/5100	1774552	5479451	NO	4	0.001	4
R25/5135	1779152	5481483	NOT TESTED		0.032	4
R25/5164	1775873	5482367	YES	4	0.455	4
R25/5165	1776019	5481886	YES	4	1.36	4
R25/5190	1776678	5478988	YES	4	2.80	4
R25/5233	1779398	5487565	NO	4	1.69	4
R26/6503	1766253	5462295	NOT TESTED		0.020	4
R26/6587	1772634	5473057	NO	3	0.530	3
R26/6624	1773933	5474297	NO	4	2.85	4
R27/0320	1756996	5434508	NOT TESTED		0.001	4
R27/1137	1773406	5444956	NOT TESTED		NT	
R27/1171	1756493	5431227	NOT TESTED		0.003	4
R27/1180	1760435	5435698	NOT TESTED		0.500	2
R27/1182	1759274	5432161	NOT TESTED		0.730	4
R27/1183	1763084	5438691	NO	4	0.310	4
R27/1265	1756998	5434516	NOT TESTED		0.083	4
R27/6418	1762218	5425695	YES	4	1.46	4
R27/6833	1777716	5445324	NO	4	0.955	4
S25/5125	1782734	5483013	NO	4	3.05	4
S25/5200	1781183	5479785	NO	4	0.001	4
S25/5256	1780491	5483153	NOT TESTED		NT	
S25/5322	1782983	5487486	NO	4	9.15	4
S26/0117	1811483	5456780	NO	4	4.00	4
S26/0223	1816203	5459285	YES	4	10.15	4
S26/0299	1818355	5461870	NO	4	3.65	4
S26/0439	1807492	5455180	NO	4	2.80	4
S26/0457	1807657	5450331	NO	4	0.45	4
S26/0467	1809272	5453850	NO	4	2.11	4
S26/0568	1813487	5451921	NOT TESTED		0.010	4
S26/0576	1813462	5452534	NOT TESTED		0.021	4
S26/0705	1810472	5454279	NO	2	1.15	2
S26/0756	1815919	5448296	NOT TESTED		0.001	1
S26/0762	1815702	5449348	YES	4	0.006	4
S26/0824	1810547	5454381	NO	4	4.85	4
S26/0846	1807902	5449492	NOT TESTED		0.895	4
S27/0009	1793895	5443481	NO	4	3.20	4
S27/0070	1797508	5443111	NO	4	0.263	4
S27/0136	1802217	5446389	NO	4	4.15	4
S27/0156	1803403	5442776	YES	4	0.021	4
S27/0202	1805461	5446520	YES	4	2.15	4
S27/0268	1793453	5434055	NOT TESTED		0.010	4
S27/0283	1797276	5436168	NOT TESTED		0.100	4
S27/0299	1796504	5438936	NO	4	0.340	4
S27/0344	1803348	5437340	NO	3	0.006	3
S27/0389	1807205	5433792	NO	3	0.240	3
S27/0396	1805859	5435962	NO	4	0.471	4
S27/0433	1787692	5427839	NOT TESTED		0.010	4
S27/0435	1787608	5430805	NOT TESTED		0.006	4
S27/0442	1789891	5426884	NOT TESTED		0.001	4
S27/0495	1797227	5431330	NOT TESTED		0.010	4
S27/0522	1803032	5431324	NO	4	3.45	4
S27/0571	1807158	5433014	NO	4	5.70	4
S27/0585	1780321	5422598	NOT TESTED		0.010	4
S27/0588	1784844	5420713	NO	4	0.051	4
S27/0594	1781351	5419721	NOT TESTED		0.029	4
S27/0602	1789626	5425302	NOT TESTED		0.004	4

S27/0607	1786289	5425037	NOT TESTED		0.051	3
S27/0614	1786778	5421924	NOT TESTED		NT	
S27/0615	1786805	5422158	NOT TESTED		0.055	4
S27/0681	1808952	5433542	YES	3	0.250	3
T26/0003	1822559	5473237	NO	4	0.625	4
T26/0087	1820296	5464750	NOT TESTED		0.975	4
T26/0099	1822518	5467619	NO	4	2.75	4
T26/0206	1822582	5467829	YES	4	1.93	4
T26/0259	1825997	5469120	NO	3	0.900	3
T26/0332	1822231	5457402	NO	3	0.950	3
T26/0413	1824486	5459979	NOT TESTED		0.001	4
T26/0430	1822131	5463028	NO	4	1.21	4
T26/0489	1827571	5461855	NOT TESTED		9.70	3
T26/0538	1827738	5461169	NO	4	10.35	4
T27/0063	1858025	5446630	NO	4	0.935	4

*Note summary statistics were calculated using Microsoft Excel Professional Plus 2010. Data with less than the laboratory's analytical detection limits were assigned a value of one half their original value

Appendix 4: Raw data

Site Name	X	Y	Date	<i>E.coli</i> (cfu/100mL)	Nitrate nitrogen (mg/L)
R25/5100	1774552	5479451	Sep-14	<1.00	<0.002
			Dec-14	<1.00	0.005
			Mar-15	<1.00	<0.002
			Jun-15	<1.00	<0.002
R25/5135	1779152	5481483	Sep-14	Not tested	0.125
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.002
			Jun-15	Not tested	0.054
R25/5164	1775873	5482368	Sep-14	5	0.280
			Dec-14	3000	0.560
			Mar-15	15	0.590
			Jun-15	24	0.350
R25/5165	1776019	5481886	Sep-14	<1.00	1.74
			Dec-14	2	0.980
			Mar-15	<1.00	1.77
			Jun-15	<1.00	0.820
R25/5190	1776678	5478988	Sep-14	<1.00	3.50
			Dec-14	4	2.20
			Mar-15	<1.00	1.95
			Jun-15	<1.00	3.40
R25/5233	1779398	5487565	Sep-14	<1.00	1.59
			Dec-14	<1.00	1.54
			Mar-15	<1.00	1.95
			Jun-15	<1.00	1.79
R26/6503	1766253	5462295	Sep-14	Not tested	0.022
			Dec-14	Not tested	0.006
			Mar-15	Not tested	0.017
			Jun-15	Not tested	0.037
R26/6587	1772634	5473057	Sep-14	<1.00	1.38
			Dec-14	<1.00	0.610
			Mar-15	<1.00	0.450
			Jul-15	Could not be sampled	Could not be sampled
R26/6624	1773933	5474297	Sep-14	<1.00	2.70
			Dec-14	<1.00	2.80
			Mar-15	<1.00	3.00
			Jun-15	<1.00	2.90
R27/0320	1756996	5434508	Sep-14	Not tested	<0.002
			Dec-14	Not tested	<0.002
			Feb-15	Not tested	<0.002
			Jul-15	Not tested	0.002
R27/1137	1773406	5444956	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	Could not be sampled	Could not be sampled
			Mar-15	Could not be sampled	Could not be sampled
			Jun-15	Could not be sampled	Could not be sampled
R27/1171	1756493	5431227	Sep-14	Not tested	0.004
			Dec-14	Not tested	<0.002
			Mar-15	Not tested	<0.002
			Jul-15	Not tested	0.021
R27/1180	1760436	5435698	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	Could not be sampled	Could not be sampled
			Mar-15	Not tested	1.01
			Jul-15	Not tested	1.00
R27/1182	1759274	5432161	Oct-14	Not tested	0.740
			Dec-14	Not tested	0.720
			Feb-15	Not tested	0.720
			Jun-15	Not tested	0.740
R27/1183	1763084	5438691	Sep-14	<1.00	0.320
			Dec-14	<1.00	0.250
			Mar-15	<1.00	0.300
			Jun-15	<1.00	0.440

Site Name	X	Y	Date	<i>E.coli</i> (cfu/100mL)	Nitrate nitrogen (mg/L)
R27/1265	1756998	5434516	Sep-14	Not tested	0.063
			Dec-14	Not tested	0.102
			Feb-15	Not tested	0.017
			Jul-15	Not tested	0.116
R27/6418	1762218	5425695	Sep-14	<1.00	1.72
			Dec-14	<1.00	1.19
			Mar-15	<1.00	1.12
			Jun-15	46	1.98
R27/6833	1777716	5445324	Sep-14	<1.00	1.02
			Dec-14	<1.00	0.970
			Mar-15	<1.00	0.220
			Jun-15	<1.00	0.940
S25/5125	1782734	5483013	Sep-14	<1.00	4.00
			Dec-14	<1.00	2.10
			Mar-15	<1.00	1.55
			Jun-15	<1.00	4.60
S25/5200	1781182	5479785	Sep-14	<1.00	<0.002
			Dec-14	<1.00	<0.002
			Mar-15	<1.00	<0.020
			Jun-15	<1.00	<0.002
S25/5256	1780491	5483154	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	Could not be sampled	Could not be sampled
			Mar-15	Could not be sampled	Could not be sampled
			Jun-15	Could not be sampled	Could not be sampled
S25/5322	1783001	5487382	Sep-14	<1.00	9.10
			Dec-14	<1.00	9.20
			Mar-15	<1.00	10.00
			Jun-15	<1.00	9.00
S26/0117	1811483	5456780	Sep-14	<1.00	5.20
			Dec-14	<1.00	5.40
			Mar-15	<1.00	2.60
			Jun-15	<1.00	2.80
S26/0223	1816203	5459285	Sep-14	<1.00	9.90
			Dec-14	2	11.80
			Mar-15	<1.00	10.10
			Jun-15	<1.00	10.20
S26/0299	1818355	5461870	Sep-14	<1.00	3.70
			Dec-14	<1.00	3.70
			Mar-15	<1.00	3.60
			Jun-15	<1.00	3.00
S26/0439	1807492	5455180	Sep-14	<1.00	2.70
			Dec-14	<1.00	3.10
			Mar-15	<1.00	2.80
			Jun-15	<1.00	2.80
S26/0457	1807657	5450331	Sep-14	<1.00	1.41
			Dec-14	<1.00	0.480
			Mar-15	<1.00	0.179
			Jun-15	<1.00	0.420
S26/0467	1809272	5453850	Sep-14	<1.00	2.60
			Dec-14	<1.00	2.90
			Mar-15	<1.00	1.56
			Jun-15	<1.00	1.62
S26/0568	1813487	5451921	Sep-14	Not tested	<0.020
			Dec-14	Not tested	0.006
			Mar-15	Not tested	<0.020
			Jun-15	Not tested	<0.020
S26/0576	1813462	5452534	Sep-14	Not tested	<0.002
			Dec-14	Not tested	0.115
			Mar-15	Not tested	0.040
			Jun-15	Not tested	<0.002

Site Name	X	Y	Date	E.coli (cfu/100mL)	Nitrate nitrogen (mg/L)
S26/0705	1810472	5454279	Sep-14	<1.00	2.30
			Dec-14	<1.00	4.50
			Mar-15	Could not be sampled	Could not be sampled
			Jun-15	Could not be sampled	Could not be sampled
S26/0756	1815919	5448296	Sep-14	Not tested	<0.002
			Dec-14	Could not be sampled	Could not be sampled
			Mar-15	Could not be sampled	Could not be sampled
			Jun-15	Could not be sampled	Could not be sampled
S26/0762	1815702	5449348	Sep-14	<1.00	<0.002
			Dec-14	<1.00	<0.020
			Mar-15	<1.00	<0.200
			Jun-15	40	<0.002
S26/0824	1810547	5454381	Sep-14	<1.00	5.00
			Dec-14	<1.00	4.90
			Mar-15	<1.00	4.80
			Jun-15	<1.00	4.80
S26/0846	1807902	5449492	Sep-14	Not tested	0.960
			Dec-14	Not tested	0.970
			Mar-15	Not tested	0.830
			Jun-15	Not tested	0.760
S27/0009	1793895	5443482	Sep-14	<1.00	3.60
			Dec-14	<1.00	3.80
			Mar-15	<1.00	2.80
			Jun-15	<1.00	2.50
S27/0070	1797508	5443111	Sep-14	<1.00	0.990
			Dec-14	<1.00	0.188
			Mar-15	<1.00	0.196
			Jun-15	<1.00	0.330
S27/0136	1802217	5446389	Sep-14	<1.00	4.80
			Dec-14	<1.00	4.70
			Mar-15	<1.00	1.70
			Jun-15	<1.00	3.60
S27/0156	1803403	5442776	Sep-14	<1.00	0.006
			Dec-14	1	0.030
			Mar-15	<1.00	0.089
			Jun-15	<1.00	0.011
S27/0202	1805461	5446520	Sep-14	<1.00	2.20
			Dec-14	<1.00	2.20
			Mar-15	3	2.10
			Jun-15	4	1.92
S27/0268	1793453	5434055	Sep-14	Not tested	<0.020
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.020
			Jun-15	Not tested	<0.020
S27/0283	1797276	5436168	Sep-14	Not tested	<0.200
			Dec-14	Not tested	<0.200
			Mar-15	Not tested	<0.200
			Jun-15	Not tested	<0.020
S27/0299	1796504	5438936	Sep-14	<1.00	0.340
			Dec-14	<1.00	0.350
			Mar-15	<1.00	0.340
			Jun-15	<1.00	0.340
S27/0344	1803348	5437340	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	<1.00	<0.200
			Mar-15	<1.00	<0.020
			Jun-15	<1.00	<0.002
S27/0389	1807205	5433792	Sep-14	<1.00	<0.002
			Dec-14	<1.00	0.780
			Mar-15	<1.00	0.240
S27/0396	1805859	5435962	Sep-14	<1.00	0.182
			Dec-14	<1.00	0.860
			Mar-15	<1.00	0.760
			Jun-15	<1.00	0.160

Site Name	X	Y	Date	<i>E.coli</i> (cfu/100mL)	Nitrate nitrogen (mg/L)
S27/0433	1787692	5427839	Sep-14	Not tested	<0.020
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.200
			Jun-15	Not tested	<0.020
S27/0435	1787608	5430805	Sep-14	Not tested	<0.020
			Dec-14	Not tested	<0.002
			Mar-15	Not tested	<0.020
			Jun-15	Not tested	<0.002
S27/0442	1789891	5426884	Sep-14	Not tested	<0.002
			Dec-14	Not tested	<0.002
			Mar-15	Not tested	<0.002
			Jun-15	Not tested	<0.002
S27/0495	1797227	5431330	Sep-14	Not tested	<0.020
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.200
			Jun-15	Not tested	<0.020
S27/0522	1803032	5431324	Sep-14	<1.00	3.20
			Dec-14	<1.00	3.40
			Mar-15	<1.00	3.50
			Jun-15	<1.00	3.50
S27/0571	1807158	5433014	Sep-14	<1.00	5.60
			Dec-14	<1.00	7.40
			Mar-15	<1.00	5.60
			Jun-15	<1.00	5.80
S27/0585	1780320	5422598	Sep-14	Not tested	0.194
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.020
			Jun-15	Not tested	<0.002
S27/0588	1784844	5420714	Sep-14	<1.00	<0.002
			Dec-14	<1.00	<0.200
			Mar-15	<1.00	0.360
			Jun-15	<1.00	<0.002
S27/0594	1781351	5419721	Sep-14	Not tested	0.006
			Dec-14	Not tested	0.050
			Mar-15	Not tested	0.055
			Jun-15	Not tested	0.007
S27/0602	1789626	5425302	Sep-14	Not tested	<0.002
			Dec-14	Not tested	0.006
			Mar-15	Not tested	<0.020
			Jun-15	Not tested	<0.002
S27/0607	1786289	5425037	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	Not tested	<0.200
			Mar-15	Not tested	<0.200
			Jun-15	Not tested	<0.002
S27/0614	1786778	5421924	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	Could not be sampled	Could not be sampled
			Mar-15	Could not be sampled	Could not be sampled
			Jun-15	Could not be sampled	Could not be sampled
S27/0615	1786805	5422158	Sep-14	Not tested	0.260
			Dec-14	Not tested	<0.020
			Mar-15	Not tested	<0.200
			Jun-15	Not tested	<0.020
S27/0681	1808952	5433542	Sep-14	Could not be sampled	Could not be sampled
			Dec-14	63	0.530
			Mar-15	<1.00	0.200
			Jun-15	<1.00	0.300
T26/0003	1822559	5473236	Sep-14	<1.00	6.00
			Dec-14	<1.00	0.730
			Mar-15	<1.00	0.300
			Jun-15	<1.00	0.520

Site Name	X	Y	Date	<i>E.coli</i> (cfu/100mL)	Nitrate nitrogen (mg/L)
T26/0087	1820296	5464750	Sep-14	Not tested	3.70
			Dec-14	Not tested	1.06
			Mar-15	Not tested	0.540
			Jun-15	Not tested	0.890
T26/0099	1822518	5467619	Sep-14	<1.00	2.80
			Dec-14	<1.00	3.00
			Mar-15	<1.00	2.70
			Jun-15	<1.00	2.50
T26/0206	1822582	5467829	Sep-14	<1.00	2.10
			Dec-14	1	1.98
			Mar-15	<1.00	1.77
			Jun-15	<1.00	1.88
T26/0259	1825997	5469120	Sep-14	<1.00	1.99
			Dec-14	<1.00	0.900
			Mar-15	<1.00	0.470
T26/0332	1822231	5457402	Sep-14	<1.00	1.19
			Dec-14	<1.00	0.950
			Mar-15	<1.00	0.410
T26/0413	1824486	5459979	Sep-14	Not tested	0.004
			Dec-14	Not tested	<0.002
			Mar-15	Not tested	<0.002
			Jun-15	Not tested	<0.002
T26/0430	1822131	5463028	Sep-14	<1.00	3.30
			Dec-14	<1.00	1.60
			Mar-15	<1.00	0.650
			May-15	<1.00	0.820
T26/0489	1827572	5461854	Sep-14	Not tested	11.40
			Dec-14	Not tested	9.70
			Mar-15	Not tested	8.10
T26/0538	1827738	5461169	Sep-14	<1.00	10.8
			Dec-14	<1.00	9.90
			Mar-15	<1.00	10.8
			Jun-15	<1.00	8.50
T27/0063	1858025	5446630	Aug-14	<1.00	0.880
			Dec-14	<1.00	1.03
			Mar-15	<1.00	0.980
			May-15	<1.00	0.890