

Groundwater quality monitoring 2010-11

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1 Introduction

1.1 Background

The groundwater quality monitoring programme gathers information to provide a basis for effective management of this resource and is a council responsibility under the Resource Management Act. It provides a snapshot of groundwater quality in the Waikato region as well as showing spatial and temporal trends. The monitoring data can be used to examine factors which influence the observed quality. Groundwater quality can also be compared with standards and guidelines to assess its suitability for various uses. In the long-term, the monitoring information enables an evaluation of the effectiveness of management of this resource. This dataset is increasingly valuable and it is important to continue gathering comprehensive and reliable data to enable informed management of our groundwater resources in the future.

The primary objective of this report is to document the groundwater quality monitoring undertaken in the period from autumn 2010 to the summer of 2010/2011. It includes annual monitoring of regional and community networks (described in sections 2 to 4) and quarterly sampling at a lesser number of sites focused on nitrate and pesticide occurrence. There are other datasets related to specific investigations, such as the Lake Taupo catchment and Coromandel coastal aquifer studies, which are not included in this report.

This data report is the first in this format since the implementation of the Regional Groundwater Monitoring Programme. Routine monitoring of groundwater began in 1995 with a relatively smaller number of sites (~30). A larger regional network of 108 wells was established in 1996 and was monitored for two years on a six monthly basis. In 2002 this network was increased to 112 and in 2004 110 of these wells were monitored annually. Approximately this number has been maintained since, although some sites have changed by necessity.

A subset of about 30 of the regional network wells has been monitored quarterly. The quarterly and annual sampling of the 'Regional' network is represented in Appendix 1. This shows that for various, predominantly logistic, reasons not all wells have the same length of record.

A 'Community', network described in section 2 was established in 2000 (Hadfield and Nicole, 2000). This comprised a total of 90 school supplies which is sampled two yearly. Other community supply information was collated from available external district supply data in 2000. A total of 89 schools were sampled in 2002/3 and 88 in 2004. A total of 80 or more school monitoring wells has been maintained in the network since. Again data records vary in length due to school closures and logistic reasons.

An electronic copy of this report can be obtained from the Waikato Regional Council website: www.waikatoregion.govt.nz/publications.

1.2 Report content

This report provides information on the routine annual monitoring of groundwater quality at regional and community sites across the Waikato region. Summary information is also provided for quarterly monitoring of about 30 sites to investigate nitrogen trends and four sites for pesticide occurrence. The annual plan performance target for regional groundwater quality monitoring is 110 regional sites and 80 community (school) sites.

The principle objectives of this report are to document the monitoring networks and present summary statistics. Recent (2010/11) regional and community network results

are compared with drinking water standards and guidelines. Trends in nitrate and pesticide occurrence at selected sites are also presented.

1.3 Water quality guidelines and standards

The drinking-water standards apply to water that is designed to be used for human consumption, food preparation, utensil washing, oral hygiene or personal hygiene. They are intended to protect public health and be appropriate for large community, as well as privately owned, drinking-water supplies.

The standards alone are not sufficient to protect against health risks from contaminated drinking-water. They define, based on current knowledge, chemical concentrations that constitute no significant health risk to a person (weighing 70 kg) who consumes two litres of that water a day over their lifetime (70 years). A degree of uncertainty over the magnitude of the risk always exists. Although the standards are set with respect to health risk, aesthetic guidelines are also provided. This is because the public generally assesses the quality of water on aesthetic perceptions. The use of multiple barriers to protect against supply contamination decreases risk and the reliance on supply treatment (MoH, 2005). Notably this includes source water protection.

Table 2 lists the maximum acceptable values for inorganic determinands of health significance from the Ministry of Health Drinking-water Standards for NZ (MoH, 2005). Datasheets for the determinands that have been found to exceed these standards are included in Appendix 5. The following table lists guideline values for aesthetic determinands, which have nuisance rather than health significance. Again datasheets are included in Appendix 5 for determinands that have been found to exceed these standards.

Table 1: Maximum acceptable values (MAVs) in mg/L for inorganic determinands of health significance (reproduced from Ministry of Health, 2005)

Name	MAV	Remarks
antimony	0.02	
arsenic	0.01	For excess lifetime skin cancer risk of 6×10^{-4} . PMAV, because of analytical difficulties
barium	0.7	
beryllium ¹	0.004	PMAV
boron ²	1.4	
bromate	0.01	For excess lifetime cancer risk of 7×10^{-5} . PMAV
cadmium	0.004	
chlorate	0.8	PMAV. Disinfection must never be compromised. DBP (chlorine dioxide)
chlorine	5	Free available chlorine expressed in mg/L as Cl ₂ . ATO. Disinfection must never be compromised
chlorite	0.8	Expressed in mg/L as ClO ₂ . PMAV. Disinfection must never be compromised. DBP (chlorine dioxide)
chromium	0.05	PMAV. Total. Limited information on health effects
copper	2	ATO
cyanide	0.08	Total cyanides
cyanogen chloride	0.08	Expressed in mg/L as CN. Total. DBP (chloramination)
fluoride ³	1.5	
lead	0.01	
lithium ¹	1	PMAV
manganese	0.4	ATO
mercury	0.002	Total
molybdenum	0.07	
monochloramine	3	DBP (chlorination)
nickel	0.02	PMAV
nitrate, short term ⁴	50	Expressed in mg/L as NO ₃ . The sum of the ratio of the concentrations of nitrate and nitrite to each of their respective MAVs should not exceed one
nitrite, long term	0.2	Expressed in mg/L as NO ₂ . PMAV (long term)
nitrite, short term ¹⁴	3	Expressed in mg/L as NO ₂ . The sum of the ratio of the concentrations of nitrate and nitrite to each of their respective MAVs should not exceed one
selenium	0.01	
silver	0.1	PMAV
uranium	0.02	PMAV

Notes: Where WHO Guideline values are based on 60 kg bodyweight, the DWSNZ uses 70 kg bodyweight. See the datasheets for calculations (WHO 2004).

- 1 MAV retained despite no WHO guideline value.
- 2 WHO guideline PMAV is 0.5 mg/L.
- 3 For oral health reasons the Ministry of Health recommends that the fluoride content for drinking-water in New Zealand be in the range of 0.7–1.0 mg/L. This is *not* a MAV.
- 4 Now short term only. The short-term exposure MAVs for nitrate and nitrite have been established to protect against methaemoglobinaemia in bottle-fed infants.

Table 2: Guideline values for aesthetic determinands (reproduced from Ministry of Health, 2005)

Determinand	GV	Units	Comments
aluminium	0.10	mg/L	Above this, complaints may arise due to depositions or discoloration.
ammonia	1.5 0.3	mg/L	Odour threshold in alkaline conditions. For control of chloramine formation in chlorinated water.
calcium			See hardness.
chloride	250	mg/L	Taste, corrosion.
chlorine	0.6–1.0	mg/L	Taste and odour threshold (MAV 5 mg/L)
2-chlorophenol	0.0001 0.01	mg/L	Taste threshold. Odour threshold.
colour	10	TCU	Appearance.
copper	1	mg/L	Staining of laundry and sanitary ware (PMAV 2 mg/L)
1,2-dichlorobenzene	0.001 0.002	mg/L	Taste threshold. Odour threshold (MAV 1.0 mg/L)
1,4-dichlorobenzene	0.0003 0.006	mg/L	Odour threshold. Taste threshold (MAV 0.4 mg/L)
2,4-dichlorophenol	0.0003 0.04	mg/L	Taste threshold. Odour threshold.
ethylbenzene	0.002 0.08	mg/L	Odour threshold. Taste threshold (MAV 0.3 mg/L)
hardness (total) (Ca + Mg) as CaCO ₃	200 100–300	mg/L	High hardness causes scale deposition, scum formation. Low hardness (<100) may be more corrosive. Taste threshold.
hydrogen sulphide	0.05	mg/L	Taste and odour threshold.
iron	0.2	mg/L	Staining of laundry and sanitary ware.
magnesium			See hardness.
manganese	0.04 0.10	mg/L	Staining of laundry. Taste threshold (MAV 0.4 mg/L)
monochlorobenzene	0.01	mg/L	Taste and odour threshold (MAV 0.3 mg/L)
odour (threshold odour number)	3		Odour should be acceptable.
pH	7.0–8.5		Should be between 7.0 and 8.0. Most waters with a low pH have a high plumbosolvency. Waters with a high pH: have a soapy taste and feel. Preferably pH <8 for effective disinfection with chlorine.
sodium	200	mg/L	Taste threshold.
styrene	0.004	mg/L	Odour threshold (MAV 0.03 mg/L)
sulphate	250	mg/L	Taste threshold.

Determinand	GV	Units	Comments
taste			Should be acceptable to most consumers.
temperature			Should be acceptable to most consumers, preferably cool.
Toluene	0.03 0.04	mg/L	Odour. Taste threshold (MAV 0.8 mg/L)
total dissolved solids	1000	mg/L	Taste may become unacceptable from 600–1200 mg/L.
trichlorobenzenes (total)	see below		(MAV 0.03 mg/L)
1,2,3-trichlorobenzene	0.01	mg/L	Odour threshold.
1,2,4-trichlorobenzene	0.005	mg/L	Odour threshold.
1,3,5-trichlorobenzene	0.05	mg/L	Odour threshold.
2,4,6-trichlorophenol	0.002 0.3	mg/L	Taste threshold. Odour threshold (MAV 0.2 mg/L)
Turbidity	2.5	NTU	Appearance. For effective terminal disinfection, median turbidity <1 NTU, single sample <5 NTU.
Xylene	0.02	mg/L	Odour threshold (MAV 0.6 mg/L)
Zinc	1.5	mg/L	Taste threshold. May affect appearance from 3 mg/L.

2 Groundwater quality monitoring networks

2.1 Monitoring well network design

The regional groundwater quality network is designed to represent the range of groundwater characteristics across the region. It is not designed to investigate the impacts on quality of specific point source discharges. Figure 1, shows the network is widely distributed spatially.

Groundwater systems are three dimensional and substantial changes in groundwater quality can occur with depth. Groundwater may therefore be monitored at the same location at various depths. Figure 2 shows the depth distribution of sampling wells in the monitoring network. This regional network was selected to represent predominantly vulnerable aquifers with relatively young groundwater primarily in aerobic condition. Wells with significant iron concentrations are under-represented in this network. There are few wells representing ‘ambient’ conditions apart from where older groundwater may have been sampled. Water quality records are not long enough to show very long-term trends which often occur in groundwater. Monitoring well construction and other details are provided in Appendix 2.

There are very few dedicated wells and therefore monitoring is dependent on access to available, predominantly privately owned wells. As a consequence there have been changes over time resulting in monitoring records of variable length (Table 1). Given that, where possible, water supply wells are drilled to avoid poor quality water and lesser permeable formation, such situations are expected to be under-represented in the network. Apart from spatial distribution, an important criterion is that wells are

properly documented to inform interpretation. This is with regard primarily to both well construction and geology. Some early exceptions are progressively being rectified.

An initial smaller groundwater monitoring network was focused on nitrate occurrence and excluded wells with iron-rich or anaerobic groundwater. About 30 of these wells have been retained as part of the regional network but are monitored quarterly (denoted with (N for 'Nitrate' sub-network) in Table 1.

Wells monitored in 2010 are summarised in Table 4 and their locations are illustrated in Figure 1. A total of 110 wells were sampled including 10 wells (*) which are monitored as part of the National Groundwater Quality Programme (NGMP). These are sampled by Waikato Regional Council for analysis by Geological and Nuclear Sciences. Also indicated are wells which four yearly are also analysed to produce for pesticide (P) and microbial (M) environmental indicators. These are environmental indicators derived from both regional and community groundwater networks, which can be found on the www.waikatoregion.govt.nz website.

A community monitoring network was introduced in 2000 for three principal reasons. The first is that they are a network of school supplies and therefore of particular interest to the community. Secondly it is an objectively determined network. Thirdly it was thought that they would provide a stable network with dependable access. This last aspect has not been as dependable as initially thought given changes to rural schools. Also as these supplies require potable water, they tend to be shutdown once exceedances occur, thereby skewing slightly the results towards higher quality. The community monitoring network is monitored every two years (due to cost and logistic constraints) and the network is illustrated in Figures 3 and 4.

The relatively low frequency of groundwater monitoring reflects the low velocities and slow changes seen in groundwater quality. Deeper groundwaters may be quite old with substantial lags being evident between land-use change and groundwater quality impacts. The low frequency of groundwater monitoring does however extend the period required to gather sufficient records for statistical analysis.

There are four wells monitored quarterly for pesticide occurrence that are also documented here (Table 4). There are wells where a range of pesticides have been detected and for which ongoing monitoring has been undertaken to enable more detailed analysis and modelling (Hadfield and Smith, 1995). These are again a subset of the regional monitoring network.

There are site sheets for each monitoring well documenting the location with finder diagrams, photos of the wells and pumping equipment, as well as listing aspects of OSH and sampling procedure. A characteristic of monitoring non-dedicated wells is that logistics frequently change and site sheets must be continually updated. Examples of site sheets for both the regional and community networks are included in Appendix IV.

Site information for the regional monitoring network is included in Table 5. This includes well and screen depths. Aquifer characteristics and land-use are also described. These are subsequently summarised as part of factor analysis.

Table 3: Regional groundwater monitoring network (wells grouped by district)

(N = quarterly nitrate monitoring; M = microbial indicator, P = pesticide indicator and * =National Groundwater Monitoring Programme)

Map No.	Well	Map Reference	Indicator
Coromandel			
1	60-12	T11:549-811	P,N,*
2	60-124	T11:514-810	
3	60-167	T12:633-487	M
4	60-190	T11:608-805	M
5	63-269	T12:674-315	M
6	60-316	T12:346-583	M
7	60-345	T12:590-559	M
8	60-348	T11:639-630	P,M
9	72-3559	T10:536-937	
10	60-407	T10:442-950	M
11	60-480	T11:331-653	M
12	72-2691	T12:658-388	
Franklin			
13	61-113	R12:832-388	P, N
14	61-126	R13:607-298	M,N
15	61-135	R12:667-367	P,M
16	61-143	R13:853-287	P,M
17	61-208	R12:668-365	N
18	61-221	R13:872-253	N
19	61-230	R13:885-276	
20	61-245	R13:800-287	P
21	61-258	R12:821-351	N, *
22	61-280	R13:845-287	P,N
23	61-54	R12:834385	P,M
24	61-59	R13:791-285	P,M,N
25	61-702	R13:874-256	
26	61-85	R12:652-359	P,M, *
27	61-93	R13:861-289	P,M, *
Hauraki			
28	63-201	T13:656-166	P,M
29	63-240	T13:592-183	
30	63-328	T13:668-215	
31	63-43	S13:229251	
32	63-57	T13:414204	P,M,N
33	63-74	S12:229-300	
34	63-78	T13:670-165	M
35	72-1223	T13:639-211	
Matamata-Piako			
36	64-108	T14:465-802	M,N
37	64-111	T14:413-846	
38	64-117	T14:565-844	N
39	64-12	T14:496-863	P,M,N

Map No.	Well	Map Reference	Indicator
40	64-120	T15:510-655	P,N,*
41	64-20	T14:531-738	P,M
42	64-43	T14:546-712	M,N
43	64-46	T14:557-780	N
44	64-50	T14:595-797	P,M,N
45	64-511	T14:544-741	*
46	64-7	T14:449-908	P,M
47	64-70	T14:557-901	M,N
48	64-831	T14:519-818	P
49	64_720	T13:372-045	*
Otorohonga			
50	65-4	S15:999-433	
51	65-6	S16:091-358	M
52	65-8	S16:135-262	P,M
Rotorua			
53	66-58	U17:048-996	M
54	66-6	U16:943-152	P,M,N
55	66-92	U17:017-019	
56	66-93	U17:017-019	P
57	66-96	U17:053-958	
South Waikato			
58	67-11	T15:535-620	N
59	67-15	T15:580-510	P,M,N
60	72-4500	T16:593-246	M
61	67-4	T16:582-244	P
62	67-404	T16:596-292	M
63	67-483	T16:582-244	
64	67-55	T16:591-395	M
65	67-573	T16:568-398	M
66	67-83	T16:598-345	
Taupo			
67	68-301	T17:656-804	M
68	68-317	T17:605-811	M
69	68-320	U18:749-747	P,M
70	72-3696	U18:771-678	P,M
71	68-912	U18:830-764	M
72	68-964	T18:506-533	*
73	72-1008	T17:526-844	P
74	72-1011	T18:674-758	
75	72-1069	T18:440-775	
76	72-1072	T18:442-602	
77	72-1081	T18:422-545	P
78	72-1082	T18:429-565	
79	72-1087	T18:442602	
80	72-1089	T18:440-775	
81	72-356	T17:685-821	
82	72-392	T17:609-813	M
83	72-431	T17:528-806	

Map No.	Well	Map Reference	Indicator
Waikato			
84	69-163	S14:156-795	P,M
85	69-1709	S14:228-743	M, *
86	69-173	S14:151-871	M,N
87	69-19	S14:193-751	P,M
88	69-248	S14:192-779	P,M
89	69-295	S14:238-717	P,M
90	69-365	S13:123-022	P,M,N
91	69-374	S14:211-746	P,M
92	69-62	S14:227-742	
93	69-81	S14:982-739	M,N
94	69-97	S14:242-816	P,M
95	62-5	S14:145-689	P,M
Waipa			
96	70-1134	S15:037-649	N, *
97	70-21	S15:238-661	M,N
98	70-22	S15:238-660	P,M,N
99	70-31	S15:295-668	M
100	70-44	S15:244-635	N
101	70-47	T15:303-689	P,M,N
102	70-50	S15:251-665	M
103	70-56	S15:204-660	P,N
104	70-65	S15:030-635	P,M,N
105	70-74	S15:040-546	P,M,N
106	70-76	T15:430-574	N
Waitomo			
107	71-1	S16:140235	
108	71-26	S16:992212	M
109	71-3	S16:936223	
110	71-4	S16:925156	
111	71-5	S16:977185	M

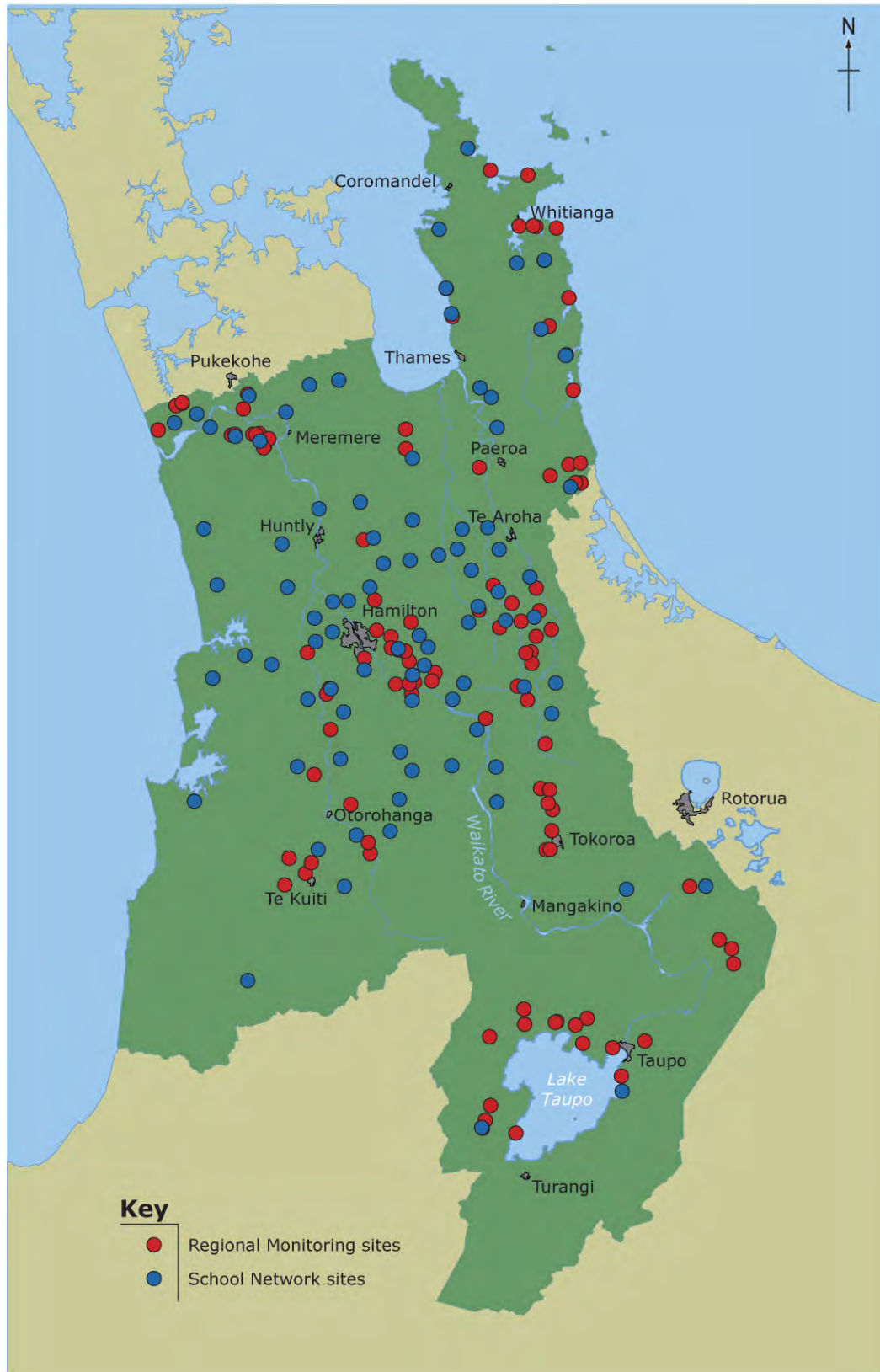


Figure 1: Groundwater monitoring well networks

Table 4: Regional groundwater monitoring network site information (from doc 1430954)

Well	Easting	Northing	Well Depth	Screen Top	Screen bottom	Lithology	Confinement	Land Use	Land Cover
62-5	2714570	6368910	6.2			Sand	Unconfined	Horticultural	High Producing Exotic Grassland
61-258	2682075	6435057	35	24.8	35	Basalt	Unknown	Agriculture	High Producing Exotic Grassland
60-4	2753610	6493800	4.1	0	4.1	Sand	Unconfined	Urban	High Producing Exotic Grassland
67-11	2753600	6362000	18.5	15.5	18.5	Pumice	Unknown	Dairy	High Producing Exotic Grassland
67-4	2758240	6324390	15			Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
67-55	2759190	6339530	127			Ignimbrite	Confined	Agriculture	High Producing Exotic Grassland
70-74	2703970	6354600	6.71	3.66	6.71	Sand	Unconfined	Urban	Built-up Area
66-58	2804800	6299600	38	32.5	38	Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
61-126	2660600	6429200	6.09			Sand	Unconfined	Dairy	High Producing Exotic Grassland
67-83	2759640	6334200	80			Ignimbrite	Unknown	Dairy	High Producing Exotic Grassland
70-21	2724000	6366100	6.41			Sand	Unconfined	Horticultural	High Producing Exotic Grassland
70-22	2723900	6365800	6.42			Sand	Unconfined	Horticultural	High Producing Exotic Grassland
60-124	2751370	6481020	6	3	6	Sand	Unconfined	Urban	Manuka and or Kanuka
70-31	2729500	6366800	4.82			Sand	Unconfined	Dairy	High Producing Exotic Grassland
60-12	2754978	6481067	9	2	6	Sand	Unconfined	Urban	High Producing Exotic Grassland
69-173	2718200	6386900	6	4	6	Pumice	Unconfined	Dairy	High Producing Exotic Grassland
61-59	2679100	6428500	26.6	19.5	26.6	Basalt	Confined	Urban	High Producing Exotic Grassland
63-57	2741465	6420005	5	3	5	Sand	Unconfined	Agriculture	High Producing Exotic Grassland
70-47	2730200	6368900	4.5	2.5	4.5	Sand	Unconfined	Dairy	High Producing Exotic Grassland
68-912	2783000	6276400				Ignimbrite	Unknown	Urban	High Producing Exotic Grassland
69-97	2724200	6381500	4.71			Sand	Unconfined	Horticultural	High Producing Exotic Grassland
61-93	2686100	6428900	26	19	26	Basalt	Unconfined	Forestry	Short-rotation Cropland
69-163	2715510	6379400	4	3.5	4	Sand	Unconfined	Urban	High Producing Exotic Grassland
64-20	2753090	6373770	9	5.2	8	Sand	Unconfined	Horticultural	High Producing Exotic Grassland
60-316	2734620	6458960	7	1	7	Gravel	Unconfined	Urban	Built-up Area
61-85	2665200	6435900	35	19.56	35	Basalt	Confined	Horticultural	High Producing Exotic Grassland
68-320	2774909	6274792	62	46	62	Ignimbrite	Unknown	Dairy	Indigenous Forest
60-186	2760688	6480260	76	24.4	76	Ignimbrite	Confined	Park/Reserve	High Producing Exotic Grassland
67-15	2757900	6350800	20			Pumice	Unconfined	Agriculture	High Producing Exotic Grassland
67-573	2756640	6339680	90			Ignimbrite	Confined	Dairy	High Producing Exotic Grassland
72-356	2768500	6282100	42	37	42	Ignimbrite	Confined	Urban	Other Exotic Forest

61-113	2683137	6438799	13	10	13	Basalt	Unconfined	Horticultural	Short-rotation Cropland
70-44	2724630	6363600				Sand	Unknown	Dairy	High Producing Exotic Grassland Orchard and Other Perennial Crops
72-1223	2763970	6421150	92.5	19.1	92.5	Ignimbrite	Confined	Urban	High Producing Exotic Grassland
67-483	2758330	6326150				Ignimbrite	Confined	Dairy	Pine Forest - Open Canopy
71-4	2692700	6316000	90		90	Limestone	Unknown	Dairy	High Producing Exotic Grassland
65-8	2713600	6326200	7	3	7	Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
60-345	2758990	6456140	27	13	27	Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
61-135	2666700	6436700	51.82	19.56	51.82	Basalt	Unconfined	Dairy	Short-rotation Cropland
72-1081	2742200	6254584	4.6	0.45	4.6	Sand	Unconfined	Urban	High Producing Exotic Grassland
68-964	2750601	6253247	5	2	5	Sand	Unknown	Agriculture	Built-up Area
72-431	2752822	6280632	48	45.7	48	Ignimbrite	Confined	Agriculture	High Producing Exotic Grassland
61-143	2685320	6428740	34	12	34	Basalt	Confined	Horticultural	Short-rotation Cropland
70-56	2720510	6365940	4.5			Sand	Unconfined	Dairy	High Producing Exotic Grassland
68-317	2760584	6281129	104	71	104	Ignimbrite	Unknown	Agriculture	High Producing Exotic Grassland
60-407	2744200	6495000	5			Sand	Unconfined	Urban	High Producing Exotic Grassland
63-328	2766800	6421500	49	19.5	49	Ignimbrite	Confined	Agriculture	High Producing Exotic Grassland
60-167	2763340	6448160	19.5	16.7	19.5	Sand	confined	Urban	High Producing Exotic Grassland
64-43	2754800	6371100	21.6	18.6	21.6	Sand	Unconfined	Urban	Urban Parkland/ Open Space
69-365	2712400	6402120	6	2.5	6	Pumice	Unconfined	Horticultural	High Producing Exotic Grassland
63-43	2722961	6424320	73	26	73	Greywacke	Confined	Agriculture	High Producing Exotic Grassland
64-12	2749570	6386340	11.5	9.5	11.5	Sand	Unconfined	Dairy	High Producing Exotic Grassland
61-702	2687400	6425600	44.5	21.46	44.5	Basalt	Unknown	Horticultural	High Producing Exotic Grassland
63-74	2722650	6430710	50.8	26.2	50.8	Greywacke	Confined	Dairy	High Producing Exotic Grassland
69-1709	2722530	6374470	5	2.5	5	Gravel	Unconfined	Dairy	High Producing Exotic Grassland
65-6	2709100	6335800	13	9.5	13	Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
64-831	2751950	6381850	9	3	9	Pumice	Unconfined	Dairy	High Producing Exotic Grassland
64-50	2759510	6379630	16.1	14.3	16.1	Pumice	Unknown	Dairy	High Producing Exotic Grassland Orchard and Other Perennial Crops
61-221	2687600	6425300	44.5	20	44.5	Basalt	Unconfined	Agriculture	High Producing Exotic Grassland
71-1	2713600	6321900	10	4	10	Sand	Confined	Agriculture	High Producing Exotic Grassland
71-26	2699270	6321295	49		49	Limestone	Confined	Agriculture	High Producing Exotic Grassland
63-240	2759200	6418300	91.5	58.5	91.5	Ignimbrite	Confined	Horticultural	High Producing Exotic Grassland
67-38	2759240	6324460	25			Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
69-248	2719200	6377900	2.75			Pumice	Unconfined	Horticultural	High Producing Exotic Grassland
69-62	2722693	6374153	9.15			Sand	Unconfined	Agriculture	High Producing Exotic Grassland

67-404	2759600	6329170	9			Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
63-78	2767000	6416500	24	13	24	Ignimbrite	Confined	Dairy	High Producing Exotic Grassland
72-1089	2744056	6277506	36.2			Ignimbrite	Confined	Agriculture	Built-up Area
72-1069	2744056	6277506	11.7	2.7	11.7	Ignimbrite	Unconfined	Agriculture	Built-up Area
60-483	2765030	6439770	8.95	6		Sand	Unconfined	Urban	Built-up Area
72-392	2760908	6281338	93			Ignimbrite	Unconfined	Agriculture	High Producing Exotic Grassland
69-81	2699220	6370780	2.25			Unknown	Unknown	Dairy	High Producing Exotic Grassland
68-301	2765617	6280398	53.6	49	53.6	Ignimbrite	Confined	Dairy	High Producing Exotic Grassland
72-1072	2744279	6260255	21	14.5	20.5	Ignimbrite	Confined	Agriculture	Other Exotic Forest
72-1087	2744279	6260225	6.6	0.6	6.6	Ignimbrite	Unconfined	Agriculture	Other Exotic Forest
									Orchard and Other Perennial Crops
69-19	2719500	6375100	3.95			Pumice	Unconfined	Dairy	Crops
70-1134	2703700	6364900	10.6	4	6	Sand	Unconfined	Horticultural	High Producing Exotic Grassland
65-4	2699900	6343300	33.6			Pumice	Unconfined	Urban	High Producing Exotic Grassland
66-92	2801700	6301890	48.5	17.2	19.16	Gravel	Unconfined	Dairy	High Producing Exotic Grassland
66-93	2801700	6301890	8	2	8	Gravel	Unknown	Urban	High Producing Exotic Grassland
71-3	2693700	6322200	26		26	Limestone	Confined	Forestry	High Producing Exotic Grassland
68-661	2777100	6267600	6	3	6	Gravel	Unconfined	Park/Reserve	Lake and Pond
66-6	2794600	6314300	38	32	38	Pumice	Unconfined	Dairy	High Producing Exotic Grassland
64-70	2755530	6389900	11.8	9.1	11.8	Pumice	Unconfined	Dairy	High Producing Exotic Grassland
61-230	2688500	6427650	43	18.3	43	Basalt	Unconfined	Horticultural	Short-rotation Cropland
61-208	2666750	6436030	18.3			Basalt	Unknown	Horticultural	High Producing Exotic Grassland
70-50	2725075	6366593	7.3			Sand	Unconfined	Urban	High Producing Exotic Grassland
61-245	2680000	6428700	14.5	8.5	14.5	Basalt	Unconfined	Horticultural	Built-up Area
64-720	2737200	6404500	6	2.8	6	Pumice	Unknown	Agriculture	High Producing Exotic Grassland
71-5	2697700	6318600	81.6		81.6	Limestone	Confined	Dairy	High Producing Exotic Grassland
60-348	2763890	6462970	13.5	6.5	13.5	Sand	Unconfined	Park/Reserve	Built-up Area
64-511	2754400	6374100	21.5	18.5	21.5	Pumice	Unknown	Dairy	Built-up Area
70-76	2742990	6357390	30			Ignimbrite	Unknown	Dairy	High Producing Exotic Grassland
69-295	2723700	6371600	6.35			Pumice	Unconfined	Horticultural	High Producing Exotic Grassland
67-435	2758498	6336196	60			Ignimbrite	Unconfined	Dairy	High Producing Exotic Grassland
64-108	2746600	6380400	23	18.5	22.5	Sand	Confined	Horticultural	High Producing Exotic Grassland
64-46	2755780	6378030	12.1			Sand	Unknown	Urban	High Producing Exotic Grassland
70-65	2703030	6363450	4.3			Unknown	Unknown	Dairy	High Producing Exotic Grassland
64-7	2745180	6390620	7.92	4.26	7.92	Pumice	Unconfined	Dairy	High Producing Exotic Grassland
64-111	2740580	6384580	83	58.3	83	Ignimbrite	Confined	Dairy	High Producing Exotic Grassland

69-374	2721100	6374500	2.93			Sand	Unconfined	Horticultural	Short-rotation Cropland
72-1008	2754600	6284400	8	2	8	Ignimbrite	Unconfined	Agriculture	High Producing Exotic Grassland
72-1082	2742928	6256557	7.98	1.99	7.98	Ignimbrite	Unconfined	Agriculture	Pine Forest - Closed Canopy
63-201	2765600	6416600	48	26	48	Ignimbrite	Unknown	Horticultural	High Producing Exotic Grassland
64-117	2756660	6384490	16	8	16	Sand	Unconfined	Dairy	High Producing Exotic Grassland
61-54	2683457	6438482	19.8	14.32	19.8	Basalt	Unknown	Agriculture	Short-rotation Cropland
66-96	2805346	6295825	116	104	116	Pumice	Unconfined	Urban	High Producing Exotic Grassland
72-1011	2767461	6275810	5.88	2.3	5.88	Ignimbrite	Unconfined	Agriculture	Lake and Pond
61-280	2684200	6428800	23.2	15.5	23.2	Basalt	Confined	Forestry	Indigenous Forest
64-120	2750980	6365660	22.2	6	22.2	Sand	Unconfined	Dairy	Short-rotation Cropland
60-480	2733090	6465270	7.7			Gravel	Unconfined	Urban	High Producing Exotic Grassland

2.2 Sample collection

Sample collection is generally consistent with the national protocol for state of environment groundwater sampling (doc 1464180) produced for the Ministry for the Environment in 2006 (MfE, 2006). The principal exception is that pH is measured in the lab rather than the field. Waikato Regional Council (WRC) does not maintain field pH instruments because more dependable results were found from lab measurement and samples are returned to the lab (located next door to WRC's offices) for analysis promptly. Another departure is that field measurement of dissolved oxygen is not always undertaken due to modifying influences such as in-situ pumps.

Sampling protocols include pre-planning, calibration of field equipment, and selection of appropriate sampling containers. At each site the water level is measured and the purge volume calculated. This is generally three annular volumes. Temperature and conductivity are monitored in a flow cell to ensure stability within 0.2 °C and 3% respectively before sampling. Filtering is undertaken in the lab with some exceptions such as sampling for the NGMP. Quality control measures undertaken are also in accordance with WRC's ISO 9001:2000 standards. These include procedures for the collection, transport and storage of samples, and methods for data verification and quality assurance to ensure the consistency of data across the programme.

After sampling, bottles are kept cooled to below 4°C but are not frozen. Samples are delivered to the lab within 48 hours and generally 24 hours. Chain of custody sheets are provided and the suite of analyses checked on delivery to the lab. Samples are analysed at an IANZ registered laboratory. Back-up samples are held for two months until results have been verified by routine quality assurance procedures. All data from field measurements and laboratory analyses are stored in WRC's water quality archiving database (HYDSTRA).

A groundwater sampling protocol summary designed to be taken into the field is included in Appendix 3.

2.3 Water quality determinands

The monitoring networks reported here have been analysed for a large number of determinands but there has been a base suite developed. Samples were analysed at Hill Laboratories (Hamilton) for what is described as 'routine' parameters comprising: pH; conductivity; total dissolved solids; alkalinity; carbon dioxide; calcium; magnesium; hardness; sodium; potassium; chloride, sulphate, boron, total iron, manganese, copper and zinc. In addition ammonium, and dissolved iron and manganese have been analysed as part of the 'base' suite, and arsenic, cadmium, and fluoride have been analysed in 106 of the samples collected in 2010.

Environment Waikato (now WRC) promoted the use of the following 'base' suite of groundwater quality laboratory determinands to aid in national reporting (Table 5). These were adopted by the Groundwater Forum in May 2006 to provide consistency between Regional Councils.

Table 5: Base suite of chemical determinands

Parameter	Detection Limit ¹	Justification
pH (7.0-8.5)	0.1 pH Units	Important for interpretation, other parameter estimation and aesthetic compliance
Electrical Conductivity	1 $\mu\text{S}/\text{cm}$	Important for ion balance check and other parameter estimation
Alkalinity	1 $\text{g}\cdot\text{m}^{-3}$ as CaCO_3	Important for interpretation and other parameter estimation
Calcium	0.02 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation (e.g. Piper plot) and ion balance ²
Magnesium	0.005 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation (e.g. Piper plot) and ion balance
Sodium (200)	0.5 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation (e.g. Piper plot) and ion balance
Potassium	0.1 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation (e.g. Piper plot) and ion balance
Nitrate-N [11.3]	0.02 $\text{g}\cdot\text{m}^{-3}$	Important nutrient management, health concern and ion balance
Chloride (250)	0.5 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation, saltwater intrusion
Sulphate (250)	0.2 $\text{g}\cdot\text{m}^{-3}$	Major ion, interpretation (e.g. Piper plot) and ion balance
Total Ammoniacal-N (1.5)	0.01 $\text{g}\cdot\text{m}^{-3}$	Nutrient management, redox/Eh estimation from nitrate/ammonium couple, (DIN), check, aesthetic
Dissolved Iron (0.2)	0.02 $\text{g}\cdot\text{m}^{-3}$	Redox indicator, (cf total iron) indicates sample quality, aesthetic, treatment consideration
Dissolved Manganese	0.005 $\text{g}\cdot\text{m}^{-3}$	Health concern, redox indicator (cf total Mn sample quality)

Note: Values given in square brackets are maximum acceptable values for drinking water (MoH, 2005). Rounded brackets provide maximum acceptable aesthetic values.

¹ Guideline only with bolded entries being more critical

² Anion/Cation balance to check data quality

Table 6: Determinands derived by calculation (from Table 5)

Calculated parameter	Justification (no cost)
Total Dissolved Salts (1000)	May be calculated from electrical conductivity
Free carbon dioxide	Calculated from alkalinity and pH
Bicarbonate	Calculated from alkalinity and pH
Carbonate	Calculated from alkalinity and pH
Total Hardness (200)	Aesthetic, practical treatment indicator, calculated from Ca and Mg

As well as the inorganic chemical determinands listed, analyses have been undertaken for a large suite of pesticides at selected locations (four wells on a quarterly basis) in the period reported. Detection limits and methods for all analyses are listed in Appendix 2.

Specification sheets listing analyses details for nitrate, pesticide and microbial indicators are available in docs 634883, 875033 and 936338.

2.4 Quality control

Quality control measures are carried out in accordance with WRC's ISO 9001:2000 standards. These include procedures for the collection, transport and storage of

samples. Data verification and quality assurance methods are also invoked to ensure data consistency. Samples are sent to an IANZ registered laboratory for analysis. Back-up samples are held for two months until results have been verified by routine quality assurance procedures.

All the data from field measurements and laboratory analysis are stored in Environment Waikato's water quality archiving database (Hydstra). For subsequent data analysis purposes, non-detect results are assumed to be half the value of the corresponding limit of detection.

2.5 Reports

Groundwater quality indicators for nitrate, pesticides and micro-organisms are reported on WRC's website www.waikatoregion.govt.nz. There are also a number of relevant sub-regional and issue related groundwater quality reports, as follows:

- Groundwater chemistry of the Mangaonua-Mangaone catchments (Marshall, 1986)
- Groundwater chemistry of the Northern Waikato District (Ringham et al., 1990)
- Groundwater resources of the Tokoroa region (Bird, 1987).
- Groundwater chemistry of the Piako catchment (Hadfield, 1993);
- Pesticide contamination of groundwater in the Waikato Region (Hadfield and Smith, 1999)
- Community groundwater supply protection (Hadfield and Nicole, 2000)
- Hydrogeology of Lake Taupo Catchment – Phase 1 (Hadfield et al., 2001)
- Hauraki groundwater quality trends 1992-2002 (Hadfield, 2003)
- Water resources of the Reporoa Basin (Piper, 2005).

WRC's State of the Environment Report briefly characterises groundwater resources in the region (Environment Waikato, 1999). The state and trends of groundwater quality are also reported nationally by GNS Science (2007).

3 Monitoring Results

3.1 Regional network results and summary statistics

Results of water quality analyses for the regional network are listed in Table 7. Summary statistics are also presented in Table 8. Non-detect results are given the half detection value for analysis purposes. There are 111 samples for all determinands except for arsenic, fluoride and cadmium which have 106.

There is very clear evidence of substantial land-use impacts on groundwater quality. The most common anthropogenic contaminant is nitrate. For simplicity, ambient nitrate-N concentrations in aerobic (or oxic) conditions may be considered to be less than 1 g m⁻³. Further arbitrary categories are listed below:

Ambient	< 1 g m ⁻³
Influenced	>1 g m ⁻³ and < 5.65 g m ⁻³ (half MAV)
Impacted	>5.65 g m ⁻³ and < 11.3 g m ⁻³ (MAV)
Excessive	>11.3 g m ⁻³

About 24% of the regional network wells have nitrate at 'ambient' concentrations. Many of these are due to the existence of anaerobic conditions. About 41% of wells are land-use' influenced and about 21% are 'impacted. Nitrate exceeded the drinking water standards at 15 wells (13.5%).

Nitrate-N results are illustrated spatially in Figures 2 and 3. Figure 2 shows regional monitoring network nitrate concentrations relative to drinking water guidelines. The concentrations are compared spatially to estimated nitrogen leaching through soils in Figure 3. It is evident that measured incidences of nitrate exceeding the drinking water standards are most common in the Pukekohe, Hamilton Basin and southern Hauraki Plains areas.

In the Hauraki Plains there is a general trend of decreasing nitrate concentration northward with progressively low-lying, finer and peaty sediments. It is associated with a change from recharge to discharge flow regimes and more reducing groundwater conditions (i.e. lower redox). Nitrate concentrations are generally highest in shallow, vulnerable aquifers and are lowest in very deep or iron-rich waters.

Table 7: Regional groundwater quality network monitoring results (concentrations in g m⁻³, conductivity in mS m⁻¹, (D) indicates dissolved rather than total concentrations).

Well Number	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Cond.	Cu	F
Coromandel												
60-12	23/11/2010	62	0.0032	0.0034	0.021	23	< .00005	< .000053	6.5	13.21	< .00053	0.06
60-124	23/11/2010	230	0.0014	0.0017	0.0199	99	< .00005	< .000053	16.4	4.62	0.0039	< .05
60-167	24/11/2010	84	0.0028	0.0036	0.0144	< .053	< .00005	< .000053	15.1	18.88	0.00088	0.08
60-190	23/11/2010	26	0.0013	0.0017	0.0198	5	< .00005	< .000053	39	17.04	0.00056	< .05
63-269	23/12/2010	13.4	< .001	< .0011	0.0165	2.5	< .00005	< .000053	28	15.3	0.0018	< .05
60-316	22/11/2010	123	< .001	< .0011	0.028	31	< .00005	< .000053	37	14.03	0.0056	0.06
60-345	24/11/2010	19.4	< .001	< .0011	0.0106	3	< .00005	< .000053	16.2	11.5	< .00053	< .05
60-348	23/11/2010	28	< .001	< .0011	0.0147	6.6	< .00005	< .000053	14.4	10.84	0.003	< .05
72-3559	23/11/2010	41	< .001	< .0011	0.023	12.6	< .00005	< .000053	28	14.75	0.00148	< .05
60-407	22/11/2010	11	< .001	< .0011	0.022	4.5	< .00005	< .000053	23	11.82	0.0103	< .05
60-480	22/11/2010	210	0.0023	0.0023	0.5	42	< .00005	< .000053	35	23	0.0035	0.28
72-2691	24/11/2010	31	0.0046	0.0121	0.029	44	< .00005	< .000053	320	117.1	0.0009	0.06
Franklin												
61-113	14/12/2010	5.6	< .001	< .0011	0.0191	6.3	< .00005	< .000053	16.5	12.1	0.00191	< .05
61-126	7/12/2010	23	< .001	< .0011	0.021	18.7	< .00005	< .000053	57	36.7	0.00074	< .05
61-135	20/12/2010	25	< .001	< .0011	0.0189	7.6	< .00005	< .000053	22	24.5	< .00053	< .05
61-143	7/12/2010	10.8	< .001	< .0011	0.0129	13.5	< .00005	< .000053	23	33.6	0.00137	< .05
61-208	7/12/2010	50	< .001	< .0011	0.04	12.3	0.00012	0.000126	55	41.8	0.031	< .05
61-221	7/12/2010	31	< .001	< .0011	0.0125	7.2	< .00005	< .000053	17.6	17	0.00123	< .05
61-230	20/12/2010	14.2	< .001	< .0011	0.0118	4.7	< .00005	< .000053	15.6	14.4	0.00096	< .05
61-245	20/12/2010	2.4	< .001	< .0011	0.03	3.6	< .00005	< .000053	37	16.3	< .00053	0.05
61-258	7/12/2010	70	< .001	< .0011	0.0136	12.4	< .00005	< .000053	21	22	0.00179	0.06
61-280	14/12/2010	19	< .001	< .0011	0.0131	7.4	< .00005	< .000053	20	22.7	0.057	< .05
61-54	14/12/2010	8.8	< .001	< .0011	0.015	2.3	< .00005	< .000053	14.2	15	< .00053	< .05
61-59	7/12/2010	11.2	< .001	< .0011	0.026	2.6	< .00005	< .000053	16	12.1	0.002	< .05
61-702	23/6/2011	35	< .001	< .0011	0.0113	7.1	< .00005	< .000053	19.4	16.8	0.00185	< .05
61-85	7/12/2010	26	< .001	< .0011	0.02	8.1	< .00005	< .000053	31	24.4	< .00053	< .05
61-93	7/12/2010	36	< .001	< .0011	0.0149	25	< .00005	< .000053	68	48.3	0.00142	< .05
Hauraki												
63-201	9/12/2010	28	< .001	< .0011	0.0092	4.5	< .00005	0.000063	10.4	10.1	0.0066	< .05
63-240	9/12/2010	60	< .001	< .0011	0.0114	12.5	< .00005	< .000053	11.4	16	< .00053	< .05
63-328	9/12/2010	41	< .001	< .0011	0.0138	7.4	< .00005	< .000053	11	12.3	< .00053	< .05
63-43	20/12/2010	11.7	< .001	< .0011	0.0159	1.77	0.00067	0.00069	24	20	< .00053	< .05
63-57	9/12/2010	28	< .001	< .0011	0.0151	12.7	< .00005	< .000053	23	26.7	< .00053	0.1
63-74	20/12/2010	110	< .001	0.0012	0.011	23	< .00005	< .000053	20	28.7	0.0021	0.08
63-78	9/12/2010	5.4	< .001	< .0011	0.013	2	< .00005	< .000053	16.5	9.34	0.00115	< .05
72-1223	9/12/2010	25	< .001	< .0011	0.0137	3.7	< .00005	< .000053	10.8	9.5	0.00071	< .05

Well Number	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Cond.	Cu	F
Matamata-Piako												
64-108	10/12/2010	12.8	< .001	< .0011	0.0167	12.7	< .00005	< .000053	23	28.8	0.00073	< .05
64-111	21/12/2010	104	< .001	< .0011	0.96	9.9	< .00005	< .000053	16	24.8	< .00053	0.38
64-117	8/12/2010	24	< .001	< .0011	0.079	27	< .00005	< .000053	34	46.2	< .00053	< .05
64-12	16/12/2010	16.5	< .001	0.0032	0.0097	14.6	0.00006	0.000071	33	29	0.00062	< .05
64-120	8/12/2010	31	< .001	< .0011	0.0104	9.1	< .00005	< .000053	7.7	14	< .00053	< .05
64-20	15/12/2010	23	< .001	< .0011	0.0168	15.6	0.00006	0.000074	25	25.9	0.0027	< .05
64-43	15/12/2010	26	0.0012	< .0011	0.022	11.3	< .00005	< .000053	16.9	21.1	0.00062	< .05
64-46	15/12/2010	25	< .001	< .0011	0.029	14.9	< .00005	< .000053	21	24.5	< .00053	< .05
64-511	8/12/2010	26	0.0012	0.0012	0.069	6.2	< .00005	< .000053	6.9	13.1	0.00061	< .05
64-7	21/12/2010	24	< .001	< .0011	0.032	20	< .00005	< .000053	28	34.7	0.00065	< .05
64-70	15/12/2010	24	0.0011	< .0011	0.0127	6.1	0.00008	0.000139	20	16.1	0.00145	< .05
64-831	21/12/2010	23	< .001	< .0011	0.0183	6.9	< .00005	< .000053	3.9	11.9	0.00091	< .05
64-720	30/11/2010	17	< .001	< .0011	0.0173	50	0.00095	0.001	131	73.8	0.037	< .05
Otorohonga												
65-4	17/12/2010	19.7	< .001	< .0011	0.011	7.9	< .00005	< .000053	24	19	0.032	< .05
65-6	17/12/2010	24	< .001	< .0011	0.012	3.7	< .00005	< .000053	11.4	10.8	0.00068	< .05
65-8	17/12/2010	21	< .001	< .0011	0.0123	5.8	< .00005	< .000053	7.8	8.92	0.00181	< .05
Rotorua												
66-58	22/6/2011	21			0.0074	1.98			2.3	5.2	< .00053	
66-6	27/01/2011	22	< .001	< .0011	0.0137	8.7	0.00008	0.000085	20	21.3	0.0044	< .05
66-92	22/6/2011	210			0.191	3.6			4.6	40.9	0.00076	
66-93	22/6/2011	36			0.022	7.4			10.1	16.9	0.0058	
66-96	22/6/2011	24			0.0079	2.9			3.0	6.4	< .00053	
South Waikato												
67-11	16/12/2010	33	< .001	< .0011	0.064	23	0.00007	0.000065	11.2	25	< .00053	< .05
67-15	16/12/2010	22	< .001	< .0011	0.0115	5.4	< .00005	< .000053	12.9	13.8	0.00077	< .05
72-4500	13/12/2010	38	< .001	< .0011	0.0103	9.5	< .00005	< .000053	11.6	16	0.00077	< .05
67-4	13/12/2010	46	< .001	< .0011	0.0159	11.5	< .00005	< .000053	15.7	19.3	0.0167	< .05
67-404	13/12/2010	28	< .001	< .0011	0.024	14.5	< .00005	< .000053	17.6	22.9	0.00065	< .05
67-435	13/12/2010	24	< .001	< .0011	0.0134	9.8	< .00005	< .000053	17.1	18	< .00053	< .05
67-483	13/12/2010	72	< .001	< .0011	0.0086	8.9	0.00014	0.0002	15.3	19.4	0.00072	< .05
67-55	13/12/2010	15.1	< .001	< .0011	0.0076	1.6	< .00005	< .000053	4.9	5.6	< .00053	< .05
67-573	13/12/2010	18.3	< .001	< .0011	0.0065	5.2	< .00005	< .000053	12.5	12.4	0.00065	< .05
67-83	13/12/2010	25	< .001	< .0011	0.0133	7.5	< .00005	< .000053	12.5	14.4	< .00053	< .05
Taupo												
68-301	26/11/2010	32	0.0101	0.0113	0.0056	5.4	< .00005	< .000053	3.9	11.62	< .00053	0.13
68-317	23/11/2010	27	0.0036	0.0037	< .0053	7.2	< .00005	< .000053	8.8	15.12	< .00053	0.11
68-320	26/11/2010	14	0.0051	0.0073	0.0136	13.1	< .00005	0.000056	11.4	22.7	0.0037	0.21
72-3696	25/11/2010	31	0.0072	0.0082	0.0198	7.6	< .00005	< .000053	7.2	14.53	0.00108	0.27
68-912	25/11/2010	38	0.0022	0.0027	0.0091	9.6	< .00005	< .000053	9	17.63	< .00053	0.29
68-964	25/11/2010	27	0.0019	0.0019	0.02	5	< .00005	< .000053	3.6	8.19	< .00053	0.06

Well Number	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Cond.	Cu	F
72-1008	25/11/2010	12.1	< .001	0.0015	0.012	5.7	< .00005	< .000053	4.2	8.3	0.008	< .05
72-1011	26/11/2010	37	0.0072	0.0075	0.006	5.6	< .00005	< .000053	5.3	12.96	< .00053	0.26
72-1069	24/11/2010	26	< .001	< .0011	0.042	4.2	< .00005	< .000053	4.2	13.9	0.0026	< .05
72-1072	24/11/2010	38	0.0051	0.0072	< .0053	6.1	< .00005	< .000053	3.6	8.7	0.0046	0.26
72-1081	25/11/2010	29	< .001	< .0011	< .0053	2.4	< .00005	< .000053	2.5	6.71	< .00053	0.06
72-1082	25/11/2010	48	< .001	< .0011	0.0057	5.2	< .00005	< .000053	3.9	11	0.00193	0.1
72-1087	24/11/2010	21	< .001	< .0011	< .0053	4.5	< .00005	< .000053	3.4	7.69	< .00053	< .05
72-1089	24/11/2010	46	0.0013	0.0017	0.076	11.9	< .00005	< .000053	4.4	18.67	< .00053	< .05
72-356	26/11/2010	30	0.0017	0.0019	0.0113	4.9	< .00005	< .000053	3.7	10	< .00053	0.12
72-392	23/11/2010	27	0.0016	0.0018	< .0053	9.5	< .00005	< .000053	7.9	17.3	0.031	0.13
72-431	23/11/2010	27	0.0046	0.0048	0.0067	5	< .00005	< .000053	3.9	8.47	0.0022	0.06
Waikato												
69-163	21/12/2010	46	< .001	0.0012	0.048	34	0.00013	0.000165	15.4	31.3	0.0036	0.05
69-1709	8/12/2010	32	< .001	< .0011	0.02	12.8	< .00005	< .000053	14.9	20.6	0.00145	0.07
69-173	10/12/2010	11.8	< .001	< .0011	0.066	17.8	0.00015	0.000169	19.8	29.4	0.00119	0.06
69-19	21/12/2010	32	< .001	< .0011	0.069	17.6	< .00005	< .000053	17.5	20.4	0.0049	< .05
69-248	21/12/2010	26	< .001	0.002	0.024	11.4	< .00005	< .000053	9.4	15.3	0.0048	< .05
69-295	22/12/2010	42	< .001	< .0011	0.0179	26	< .00005	0.000056	30	51.4	0.0077	< .05
69-365	10/12/2010	29	< .001	0.003	0.027	16	< .00005	< .000053	24	28	0.00152	< .05
69-374	22/12/2010	28	< .001	< .0011	0.165	43	0.00006	0.000064	56	52.4	0.0022	< .05
69-62	21/12/2010	23	< .001	< .0011	0.27	9.3	< .00005	< .000053	7.1	16.1	< .00053	< .05
69-81	8/12/2010	13.1	< .001	< .0011	0.021	5	< .00005	< .000053	9.7	13.5	0.00118	< .05
69-97	22/12/2010	25	< .001	< .0011	0.0177	10.5	< .00005	< .000053	13.9	18.2	0.0081	< .05
62-5	16/12/2010	26	< .001	< .0011	0.053	12.3	< .00005	< .000053	19	21.6	0.00123	< .05
Waipa												
70-1134	8/12/2010	16.2	< .001	< .0011	0.0077	6.8	< .00005	< .000053	11.1	12.4	0.00059	< .05
70-21	15/12/2010	47	< .001	< .0011	0.0126	31	< .00005	< .000053	8.7	25.2	0.0034	< .05
70-22	15/12/2010	43	< .001	< .0011	0.033	24	< .00005	< .000053	18.3	31.2	0.003	< .05
70-31	10/12/2010	24	< .001	< .0011	0.041	15.3	< .00005	< .000053	18.1	23.9	< .00053	< .05
70-44	5/12/2008	51	< .001	0.0035	0.028	19	< .00005	< .000053	16	29.6	0.073	< .05
70-47	9/12/2010	21	< .001	< .0011	0.0175	25	< .00005	< .000053	19.4	25.3	0.0043	< .05
70-50	15/12/2010	62	< .001	< .0011	0.037	32	< .00005	< .000053	19.3	36.6	0.0075	< .05
70-56	16/12/2010	28	< .001	< .0011	0.0183	21	< .00005	< .000053	25	14.1	< .00053	< .05
70-65	8/12/2010	12.3	< .001	< .0011	0.0081	7.3	< .00005	< .000053	13.6	15.8	0.001	< .05
70-74	8/12/2010	10.3	< .001	< .0011	0.0195	5.6	< .00005	< .000053	8.8	10.9	0.0068	< .05
70-76	8/12/2010	19.7	< .001	< .0011	0.0097	5.4	< .00005	< .000053	12.4	13.2	< .00053	0.06
Waitomo												
71-1	17/12/2010	26	< .001	< .0011	0.015	5.9	< .00005	< .000053	8.5	11.6	< .00053	< .05
71-26	17/12/2010	154	< .001	< .0011	0.0147	59	< .00005	< .000053	8.1	32.4	< .00053	< .05
71-3	17/12/2010	192	< .001	< .0011	0.0196	76	< .00005	< .000053	8.1	39.6	0.0048	0.07
71-4	17/12/2010	176	< .001	0.005	0.0142	77	0.00009	0.00111	8.6	36	0.0104	< .05
71-5	17/12/2010	112	0.0061	0.0068	0.023	43	< .00005	< .000053	8.3	27.3	< .00053	0.06

Well Number	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na	NH ₄	NO ₃ -N	pH
Coromandel												
60-12	< .02	< .021	1	63	1.27	1.08	< .0005	< .00053	5.8	< .01	1.22	8.1
60-124	< .02	0.027	10.4	260	2.1	3.7	0.0009	0.00146	12.9	< .01	3.5	7.6
60-167	0.1	0.27	8.6	< 1	0.52	< .021	< .0005	< .00053	45	< .01	< .05	7.3
60-190	< .02	0.039	29	23	7.9	2.5	< .0005	0.00056	23	< .01	< .05	6.3
63-269	< .02	0.056	11.2	17.3	2.2	2.7	0.0006	0.00067	19.1	< .01	2.4	6.4
60-316	< .02	0.059	65	111	1.21	8.2	0.0047	0.0045	35	< .01	0.62	6.6
60-345	< .02	< .021	27	14.3	3.7	1.68	0.0058	0.006	13.2	< .01	1.58	6.2
60-348	< .02	0.022	35	27	1.33	2.7	0.0008	0.00105	11.6	< .01	0.63	6.2
72-3559	< .02	0.46	18.6	41	0.66	2.3	0.004	0.0087	19.5	0.018	0.05	6.6
60-407	< .02	1.53	8.2	22	1.37	2.5	0.0027	0.0067	15.7	< .01	3.1	6.4
60-480	< .02	< .021	35	167	3.8	15.2	0.02	0.02	77	< .01	0.6	7.1
72-2691	5.4	9.4	31	220	18.9	26	0.56	0.6	95	0.21	< .05	6.3
Franklin												
61-113	< .02	0.89	12.6	25	0.48	2.3	0.0123	0.038	13.2	< .01	5.6	6
61-126	< .02	< .021	10.9	83	3.7	8.8	0.0043	0.0044	26	0.011	6.2	6.6
61-135	< .02	< .021	6.8	56	1.28	8.9	< .0005	< .00053	24	< .01	14.5	6.9
61-143	< .02	< .021	6.1	88	1.87	13.2	0.0026	0.0029	21	< .01	25	6.6
61-208	< .02	0.59	37	85	0.99	13.2	0.0028	0.0036	44	< .01	12.1	6.4
61-221	< .02	< .021	16.9	45	1.14	6.6	< .0005	< .00053	13.9	< .01	5.2	6.6
61-230	< .02	0.153	24	33	1.22	5.1	0.0013	0.00171	13.9	< .01	7	6.1
61-245	< .02	0.044	50	22	1.91	3.1	0.23	0.24	18	< .01	0.15	5
61-258	< .02	0.028	7.2	72	1.98	10.1	< .0005	0.00114	15.6	< .01	2.5	7.3
61-280	< .02	0.07	18.6	58	1.15	9.5	0.0031	0.0032	18.5	< .01	14	6.3
61-54	< .02	2.3	16.4	29	0.86	5.7	0.0031	0.0044	15.7	< .01	9.6	6
61-59	< .02	0.03	11.5	18.8	1.14	3	0.0044	0.0046	14.3	< .01	4.3	6.3
61-702	< .02	0.03	5.3	46	1.03	6.8	0.0008	0.00077	13.1	< .01	4.8	7.1
61-85	< .02	< .021	19.5	54	1.38	8.2	0.0007	0.00069	23	< .01	9.8	6.4
61-93	< .02	< .021	15	156	2.4	23	< .0005	< .00053	23	< .01	19.3	6.7
Hauraki												
63-201	2.8	4.5	22	18	1.71	1.66	1.04	1.07	10.4	0.122	< .05	6.4
63-240	< .02	< .021	5.3	53	2.4	5.2	< .0005	< .00053	12.4	< .01	0.16	7.4
63-328	< .02	< .021	4.7	33	2.3	3.5	< .0005	< .00053	11.7	< .01	0.06	7.2
63-43	< .02	0.49	31	15	4	2.6	0.0052	0.0057	29	< .01	10.4	5.9
63-57	0.06	0.58	14.6	72	7.2	9.7	0.0128	0.013	17.2	0.036	10	6.6
63-74	< .02	0.64	9	98	3.5	9.8	0.026	0.034	22	< .01	0.05	7.4
63-78	< .02	0.78	15.3	10.1	1.99	1.23	0.001	0.0034	12.3	0.036	1.72	5.8
72-1223	< .02	0.136	18.1	15.5	3.5	1.51	0.0022	0.0037	11.4	< .01	0.16	6.4
Matamata-Piako												
64-108	< .02	< .021	27	60	9.3	6.7	0.0013	0.00127	19.7	< .01	19.8	6
64-111	1.04	1.48	7.9	37	2.4	2.9	0.31	0.34	38	< .01	< .05	7.4
64-117	< .02	0.06	20	114	39	11.5	0.0119	0.0122	16.6	< .01	22	6.4

Well Number	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na	NH ₄	NO ₃ -N	pH
64-12	0.13	3	18.1	72	6.6	8.7	0.009	0.0136	19.7	0.188	7.1	6.3
64-120	< .02	0.031	20	36	4.7	3.2	< .0005	0.00196	11.7	< .01	2.6	6.5
64-20	< .02	< .021	35	68	6.7	7	0.0023	0.0028	14.4	< .01	7	6.1
64-43	< .02	< .021	17.5	51	6.9	5.5	< .0005	< .00053	14.7	< .01	8.7	6.5
64-46	< .02	< .021	24	66	6.7	7	0.0005	0.00056	15.1	< .01	4	6.3
64-511	< .02	< .021	17.5	28	5.1	3	< .0005	< .00053	12	< .01	3.4	6.5
64-7	< .02	< .021	18.8	102	10.4	12.3	< .0005	< .00053	17	< .01	13.4	6.4
64-70	< .02	< .021	26	33	4.1	4.3	3.2	3.3	12.5	0.016	0.86	6.3
64-831	< .02	0.61	4.8	33	2.7	3.9	< .0005	0.0104	7.9	< .01	5.5	7
64-720	0.08	3.1	38	220	15.8	24	0.24	0.24	34	0.61	24	5.9
Otorohonga												
65-4	< .02	2	11.4	37	5.8	4.1	0.0038	0.0046	17.5	< .01	8.1	6.5
65-6	< .02	0.03	11.5	17.3	5.1	1.94	< .0005	< .00053	12.1	< .01	2.2	6.6
65-8	< .02	1.73	15.7	25	1.94	2.5	0.0161	0.021	6.6	< .01	0.39	6.4
Rotorua												
66-58	< .02	< .021	3.7	9.7	1.2.9	1.16	< .0005	< .00053	6.4	<0.01	0.2	7.1
66-6	< .02	< .021	25	38	10.2	3.8	0.034	0.035	19.2	< .01	7.9	6.2
66-92	0.67	0.86	7.5	12.6	1.53	0.89	0.174	0.178	86	1.4	< .05	7.8
66-93	0.65	0.84	24	25	6.8	1.64	0.33	0.31	16.6	0.058	4.3	6.5
66-96	0.81	1.66	5.9	12.2	2.2	1.19	0.0059	0.0065	6.7	<0.01	0.44	6.9
South Waikato												
67-11	< .02	< .021	25	79	8.2	5.4	< .0005	< .00053	10.2	< .01	11.7	6.4
67-15	< .02	< .021	20	26	7.4	3	< .0005	< .00053	11.1	< .01	4.3	6.3
72-4500	< .02	< .021	36	39	3.8	3.6	< .0005	< .00053	14.7	< .01	3.8	6.3
67-4	< .02	2.3	30	46	3.6	4.3	0.0015	0.003	16.9	< .01	4.8	6.5
67-404	< .02	0.038	45	58	7.9	5.3	0.0017	0.00173	13.7	< .01	10.3	6.1
67-435	< .02	< .021	28	43	4.8	4.5	< .0005	< .00053	13.4	0.01	7.3	6.2
67-483	0.04	0.143	46	36	3.9	3.3	0.183	0.185	24	< .01	< .05	6.5
67-55	< .02	< .021	7.1	7.6	3.5	0.87	< .0005	< .00053	6.3	< .01	0.93	6.6
67-573	< .02	0.091	25	24	4.3	2.6	0.0012	0.00118	10.8	< .01	5.1	6.2
67-83	< .02	< .021	29	32	3.7	3.1	< .0005	< .00053	11.7	< .01	5	6.2
Taupo												
68-301	< .02	0.035	8	29	1.61	3.7	< .0005	0.00134	12.8	< .01	2.8	6.9
68-317	< .02	< .021	11.4	33	3.3	3.5	< .0005	< .00053	15.6	< .01	4.8	6.7
68-320	< .02	0.71	6.7	61	2.5	6.8	0.0134	0.0149	16.2	< .01	8.5	6.6
72-3696	< .02	0.021	12.8	34	0.69	3.6	< .0005	0.00054	14.9	< .01	4.2	6.7
68-912	< .02	0.29	17.5	40	3	3.9	0.0015	0.027	15.7	< .01	3.3	6.6
68-964	0.05	0.11	21	24	2.6	2.7	0.0018	0.00179	6.2	< .01	0.29	6.4
72-1008	< .02	2.8	4.3	24	4.6	2.4	< .0005	0.081	4.5	< .01	2.6	6.8
72-1011	< .02	< .021	11.5	28	1.72	3.3	< .0005	< .00053	16.8	< .01	2.7	6.8
72-1069	< .02	1.02	27	16.7	29	1.49	< .0005	0.01	4.1	< .01	3.6	6.3
72-1072	1.64	3.6	11.6	24	2.4	2	0.58	0.69	9.3	0.133	0.07	6.8

Well Number	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na	NH ₄	NO ₃ -N	pH
72-1081	4	5.5	30	9.3	2.8	0.8	0.154	0.161	5.9	< .01	< .05	6.3
72-1082	4.2	6.2	30	23	3.9	2.5	0.141	0.168	9.7	0.45	< .05	6.5
72-1087	< .02	0.066	8.8	16.5	3.5	1.24	< .0005	0.0033	7.7	< .01	2.3	6.7
72-1089	< .02	0.4	27	51	5.3	5	0.001	0.00165	15.5	< .01	5	6.5
72-356	< .02	0.135	14.5	22	2.2	2.5	0.0009	0.00116	10.2	< .01	1.78	6.6
72-392	< .02	0.179	10.9	45	2.7	5.1	0.0022	0.0025	16.3	< .01	5.3	6.7
72-431	< .02	< .021	7.3	24	1.67	2.9	< .0005	< .00053	8.8	< .01	1.78	6.9
Waikato												
69-163	0.04	2.2	39	116	10.1	7.9	0.057	0.082	9.5	0.011	8.3	6.4
69-1709	< .02	< .021	12.9	56	4	5.8	< .0005	< .00053	16	< .01	7	6.7
69-173	< .02	0.117	37	65	27	5.1	0.066	0.072	10.4	< .01	6.6	5.8
69-19	< .02	0.92	13	68	4.8	5.8	0.0013	0.055	9.3	< .01	7.5	6.7
69-248	< .02	1.5	15.9	47	3.6	4.4	0.0014	0.035	8.7	< .01	2	6.5
69-295	0.1	0.47	33	141	11.7	18.3	0.0015	0.017	37	< .01	7.3	6.4
69-365	< .02	0.44	19.1	79	11.6	9.6	0.057	0.056	13.5	< .01	5.4	6.5
69-374	< .02	< .021	21	198	5.8	22	0.0011	0.00102	15.2	< .01	24	6.4
69-62	< .02	< .021	9.9	51	2.6	6.8	< .0005	< .00053	9.3	< .01	8.3	6.7
69-81	< .02	< .021	35	24	5.6	2.9	0.0015	0.00166	12.3	< .01	2.4	5.9
69-97	< .02	< .021	26	48	4.6	5.2	0.0007	0.0006	14.4	< .01	5.5	6.3
62-5	< .02	< .021	19.5	60	7	7	< .0005	< .00053	12.6	< .01	7.5	6.4
Waipa												
70-1134	< .02	0.15	16.2	36	2.3	4.5	< .0005	0.012	7.6	< .01	2.6	6.3
70-21	< .02	0.049	17.1	94	4.3	4.3	0.013	0.0168	8	0.08	9.4	6.7
70-22	< .02	< .021	34	101	8.5	9.6	0.0007	0.00105	13	< .01	12	6.4
70-31	< .02	< .021	13.2	61	11.1	5.5	0.0058	0.0071	12.9	0.29	8.9	6.6
70-44	0.035	8.6	8	89	7.3	10	0.035	0.049	21	0.03	13	7.1
70-47	< .02	0.5	14.2	90	6.6	6.8	0.0013	0.0121	9.5	< .01	3.9	6.5
70-50	< .02	0.36	38	106	19.6	6.6	0.0013	0.0051	13.9	< .01	14.2	6.5
70-56	< .02	< .021	23	96	5	10.4	< .0005	< .00053	13.4	< .01	12	6.4
70-65	< .02	0.026	8.9	37	4	4.6	0.0044	0.0051	12.3	< .01	1.9	6.4
70-74	< .02	< .021	10.8	24	2.4	2.5	< .0005	< .00053	10.3	< .01	5.6	6.3
70-76	< .02	< .021	19.3	25	4.9	2.8	< .0005	< .00053	12.1	< .01	4.3	6.3
Waitomo												
71-1	< .02	< .021	14.5	29	1.22	3.5	0.001	0.00164	9.9	< .01	3.5	6.6
71-26	< .02	< .021	4.4	158	1.63	2.8	< .0005	< .00053	8	< .01	0.76	7.8
71-3	< .02	4.8	17.5	199	1.26	2.4	< .0005	0.0073	7.7	< .01	1.1	7.3
71-4	< .02	12.8	7.9	210	2.3	4.8	< .0005	0.34	5.8	< .01	2.4	7.6
71-5	< .02	< .021	2.7	121	2.2	3.4	< .0005	< .00053	9.7	0.013	< .05	7.9

Well Number	SO ₄	T.D. Solids	Temperature	Zn (D)	Zn
Coromandel					
60-12	5.5	111	15.9	< .001	0.0011
60-124	30	370	16.1	0.0096	0.0136
60-167	1.5	141	17.4	< .001	< .0011
60-190	5.6	138	19.6	0.043	0.054
63-269	6.4	105	18.5	0.0017	0.0016
60-316	19.2	270	17.7	0.0168	0.0171
60-345	2.7	77	18	0.0037	0.0038
60-348	8	86	17.2	< .001	0.0017
72-3559	8.4	130	16.6	< .001	0.0025
60-407	6.7	95	16.8	0.0114	0.0139
60-480	88	460	19.2	0.0114	0.0124
72-2691	0.7	780	19.7	0.0022	0.0116
Franklin					
61-113	4.8	86	17.1	0.0153	0.032
61-126	29	250	16.4	0.0081	0.0088
61-135	2.6	168	16.3	0.1	0.102
61-143	0.9	230	18.2	0.0058	0.0049
61-208	8.4	280	16.7	0.09	0.09
61-221	1.8	117	15.5	0.052	0.055
61-230	1.7	98	15.8	0.0039	0.0038
61-245	10.2	110	16	0.0058	0.0052
61-258	2.2	156	17.6	0.0029	0.0064
61-280	1.6	152	16.8	0.0055	0.0053
61-54	1.5	101	15.6	0.0061	0.0154
61-59	2.8	82	14.5	0.005	0.0058
61-702	2.3	113	15.9	0.014	0.0088
61-85	2.7	166	16.5	0.124	0.129
61-93	1.5	320	15.8	0.0051	0.0035
Hauraki					
63-201	0.7	68	15.4	0.21	0.29
63-240	2	110	17.9	0.56	0.59
63-328	2.5	84	17.7	0.087	0.094
63-43	2.1	135	16.3	1.52	1.51
63-57	18.9	180	15.9	0.0028	0.0024
63-74	7.8	195	18.5	0.037	0.051
63-78	1.9	63	15.2	0.0033	0.0049
72-1223	2.2	65	17.2	0.034	0.039
Matamata-Piako					
64-108	6.7	196	16.7	0.0082	0.0074
64-111	0.5	167	19.4	0.025	0.035
64-117	44	310	15.6	0.0115	0.0132
64-12	37	195	16.2	0.0032	0.0033
64-120	10.6	97	17	0.0027	0.0068
64-20	28	178	15.7	0.0044	0.0034
64-43	10.8	148	17.6	0.0016	0.0013
64-46	36	168	15.5	0.0039	0.0033
64-511	7.8	90	16.3	< .001	0.002
64-7	40	240	16.3	0.0085	0.0077
64-70	15.9	111	16.9	0.0149	0.0137
64-831	6.8	80	17.9	0.0017	0.0071
64-720	33	500	15.6	0.38	0.38
Otorohonga					
65-4	1.1	131	15.6	0.101	0.1
65-6	1.6	74	16.1	0.0037	0.0035
65-8	8.1	60	15.5	0.0017	0.0014
Rotorua					
66-58	1.3	35	13		<0.0011
66-6	12.2	143	14.1		0.0127
66-92	<0.5	270	21.7		0.0077
66-93	11.4	113	16.9		0.0032
66-96	1.9	43	13.4		<0.0011
South Waikato					
67-11	21	170	15.5	0.161	0.165
67-15	6.8	95	15	0.0106	0.0108
72-4500	7.6	110	13.7	0.033	0.034
67-4	5.6	133	13.1	0.021	0.026

Well Number	SO ₄	T.D. Solids	Temperature	Zn (D)	Zn
67-404	7.1	155	14.2	0.0052	0.0051
67-435	7.2	126	16.5	0.0016	0.0021
67-483	3.3	133	13.1	0.033	0.037
67-55	1	39	14	0.0011	0.0022
67-573	0.8	83	13.8	0.0043	0.0119
67-83	4.4	98	14.3	0.0087	0.0086
Taupo					
68-301	9.1	79	12	0.0017	0.0103
68-317	11.9	102	11.8	0.002	0.005
68-320	38	155	14.6	0.0196	0.021
72-3696	12	99	14.6	0.0078	0.0096
68-912	18.9	121	17.6	0.0037	0.0074
68-964	6	56	13.2	< .001	< .0011
72-1008	9.1	56	16.1	0.0133	0.041
72-1011	7.6	88	12.8	< .001	< .0011
72-1069	12.2	93	13.5	0.0018	0.0153
72-1072	< .5	58	12.6	< .001	0.004
72-1081	0.6	45	12.3	0.0026	0.0029
72-1082	< .5	74	13.4	0.0015	0.0046
72-1087	3.4	54	12.7	< .001	< .0011
72-1089	15.7	126	13.5	0.0133	0.022
72-356	6.4	67	12.2	0.03	0.03
72-392	23	118	12	0.059	0.064
72-431	3.9	60	12.1	0.0082	0.0175
Waikato					
69-163	53	220	17.8	0.065	0.08
69-1709	14	145	15.6	0.0018	0.002
69-173	59	200	15.2	0.05	0.052
69-19	10	142	15.7	0.0101	0.017
69-248	23	106	16.7	0.0062	0.019
69-295	131	350	15.5	0.047	0.052
69-365	41	189	15.8	0.0128	0.0143
69-374	44	360	15.7	0.0128	0.0121
69-62	14	115	16.2	0.0024	0.0036
69-81	16.5	91	16.3	0.0151	0.0157
69-97	17.3	124	18.2	0.025	0.031
62-5	16.4	147	15.5	0.0049	0.0035
Waipa					
70-1134	9.8	86	16.3	0.0014	0.0032
70-21	23	176	16.5	0.0163	0.0176
70-22	29	210	16.8	0.042	0.042
70-31	21	163	14.9	0.0035	0.0031
70-44	21	200	16.9		0.075
70-47	48	174	17.3	0.0036	0.0053
70-50	26	250	15.7	0.03	0.034
70-56	23	95	15.6	0.0018	0.0018
70-65	27	108	16	0.035	0.035
70-74	3.7	80	15.7	0.0178	0.018
70-76	1.4	90	16.2	0.0019	0.003
Waitomo					
71-1	2.7	77	14.5	0.002	0.0026
71-26	5	220	15.3	0.0194	0.022
71-3	7.9	270	15.1	< .001	0.0047
71-4	4.8	250	15.9	0.071	0.48
71-5	18.4	187	14.7	0.0022	0.0019

Table 8: General groundwater quality statistics for the 111 regional well network (concentrations in g m⁻³, conductivity in mS m⁻¹, (D) indicates dissolved rather than total concentrations).

Determinand	Mean	Median	Min	Max	St dev	Skew	Non-detect
Alkalinity	40.1	26	2.4	230	43.18	2.89	0
As	0.0014	0.0005	0.0005	0.0121	0.002	3.01	80
B	0.0379	0.0159	0.0026	0.96	0.11	7.08	5
Ca	14.45	8.9	0.025	99	16.18	2.81	1
Cd	0.00006	0.000026	0.000026	0.0011	0.0001	5.75	90
Cl	20.4	15.3	2.3	320	32.89	7.39	0
Cond.	21.1	17	4.62	117.1	14.62	3.31	0
Cu	0.00423	0.00096	0.00026	0.073	0.01	4.55	36
F	0.053	0.025	0.025	0.38	0.07	3.10	77
Fe (D)	0.205	0.01	0.01	5.4	0.805	4.95	43
Fe	0.86	0.044	0.01	12.8	1.99	3.72	93
Free CO ₂	19.09	17.5	1	65	11.61	1.01	0
Hardness	59.15	41	0.5	260	51.50	1.85	1
K	5.02	3.5	0.48	39	5.74	3.42	0
Mg	5.61	4.1	0.01	26	4.84	2.23	1
Mn (D)	0.069	0.0013	0.00025	3.2	0.33	8.31	29
Mn	0.078	0.003	0.00026	3.3	0.34	8.13	41
Na	16.82	13.4	4.1	95	13.87	3.73	0
NH ₄	0.038	0.005	0.005	1.4	0.15	7.20	92
NO ₃ -N	5.48	4.2	0.025	25	5.61	1.59	10
pH	6.57	6.5	5	8.1	0.47	0.74	0
SO ₄	14.09	7.8	0.25	131	18.56	3.28	3
TDS	151.88	124	35	780	104.29	2.82	0
Temp.	15.8	15.9	11.8	21.7	1.83	0.01	0
Zn (D)	0.043	0.0079	0.0005	1.52	0.16	7.85	10
Zn	0.049	0.0096	0.0005	1.51	0.16	7.16	6

If previous 2009 sampling from wells 66_58, 66_92, 66_93, 66_96 and 61_702 were included, the mean and maximum concentrations for arsenic would be 0.0075 and 0.66 g m⁻³ respectively.

3.2 Comparison of regional results with drinking water standards and guidelines

The quality of groundwater in the regional network has been compared against drinking water standards in Table 9 and aesthetic guidelines in Table 10. These are reported as exceedances of Maximum Acceptable Value (MAV) and half MAV (inclusive of those exceeding the MAV) for measured determinands of health significance. The latter is an arbitrary level used by the Ministry of Health to identify chemicals which ought to be monitored (priority two after micro-organisms) as they are more likely to reach the MAV over time.

It is evident from Table 9, that the most commonly occurring contaminant of concern in respect to health is nitrate. It is also highly mobile and is the most feasible to manage, given it is the result of land-use activities. Given the above, the groundwater monitoring reported here is focused primarily on nitrate occurrence and trends. It should be noted that all groundwater contamination is very difficult to remediate and hence protection is a more effective strategy.

Table 9: Regional groundwater quality comparison with drinking-water standards

Determinand	>MAV	>half MAV
Arsenic	2 (1.8%)	7 (5.7%)
Boron	0	0
Cadmium	0	0
Fluoride	0	0
Manganese	4 (3.6%)	9 (8.1%)
Nitrate	15 (13.5%)	38 (34.2%)
Copper	0	0

Arsenic is a contaminant of particular concern for human health (Appendix V) and exceeds the drinking-water standards in about 2% of wells in the regional network. Exceedences often occur in wells with geothermal influence (Piper and Kim, 2006). Although its occurrence is natural, concentrations can be exacerbated by drainage and pumping. Two wells (66_58 and 66_92) previously found to exceed the MAV for arsenic on previous occasions were not analysed for this determinand in this period.

Manganese is naturally occurring and now classified as a parameter of health significance. It is typically associated with iron and occurs in anaerobic conditions. Manganese can be readily treated, typically with aeration and sand or other filters.

Cadmium has only recently been monitored and has a very low MAV of 0.004 g m⁻³ because it accumulates in the kidneys and has a long biological half life. One of the more likely causes of cadmium entering drinking-water is from the dissolution of galvanised pipes in which it is an impurity associated with the zinc. Although one well (66_93) was found to have cadmium exceeding the MAV in previous monitoring, it was not analysed for on this occasion.

Comparison of regional groundwater quality with aesthetic guideline values shows that pH most commonly falls outside the ideal range. This is indicative of corrosion concerns relating to typically acidic waters.

Iron and manganese, which typically are elevated together (Daughney, 2003) are common nuisance chemicals causing staining and scaling problems. High concentrations occur in anaerobic and peat influenced waters.

Table 10: Regional groundwater quality comparison with aesthetic guideline values (GV)

Determinand	>GV ¹
Ammonia	3 (2.7%)
Chloride	1 (0.9%)
Copper	0
Hardness	4 (3.6%)
Iron	40 (36%)
Manganese	19 (17%)
pH	93 (83.8%)
Sodium	0
Sulphate	0
Zinc	1 (0.9%)

¹ or outside range for pH

Groundwaters in the Waikato are typically slightly acid and hence fall outside the aesthetic guideline range. Acid waters can be problematic for corrosion. It has no direct health concern but may influence the solubility and occurrence of other ions.

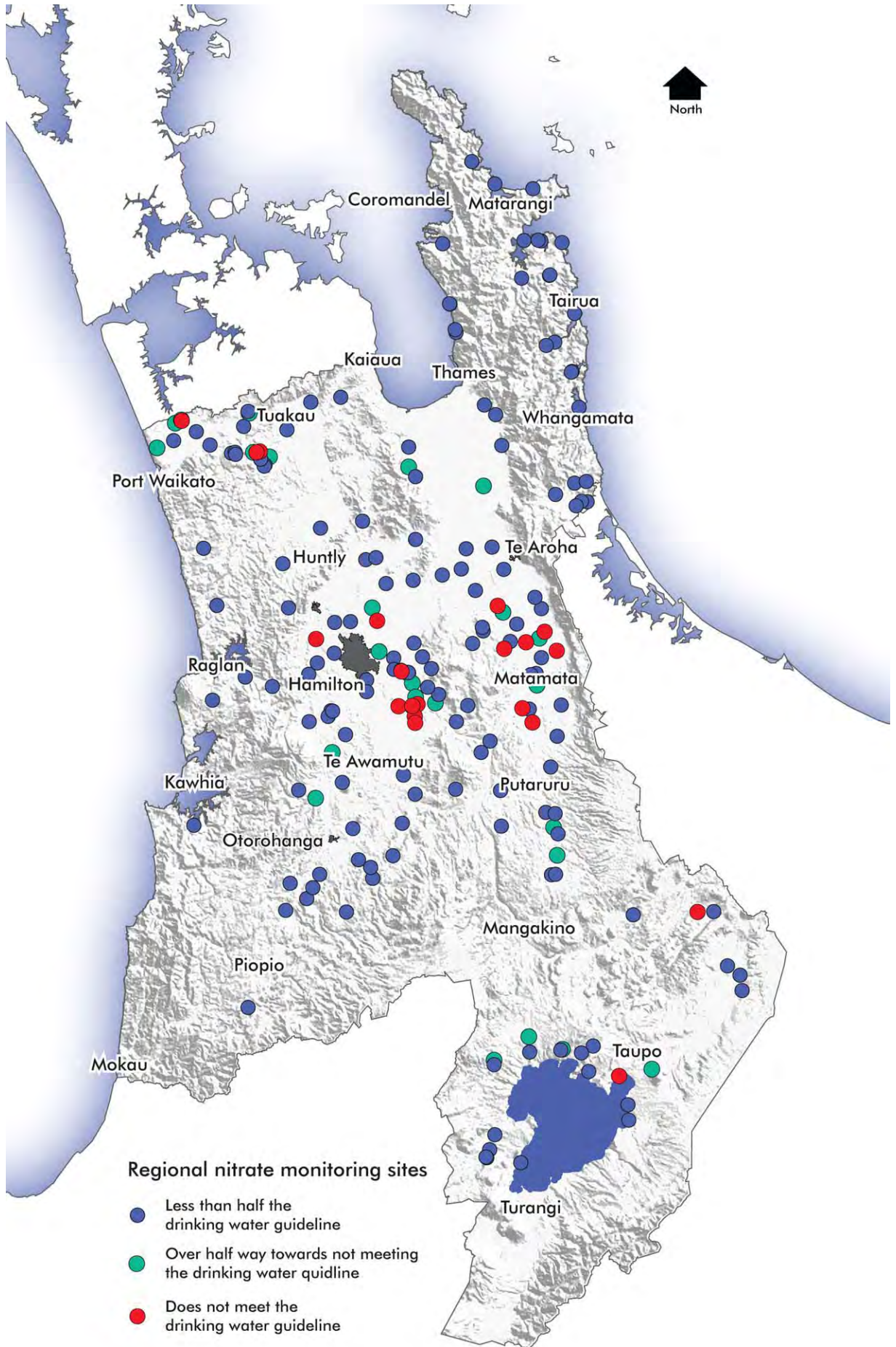


Figure 2: Regional monitoring network nitrate concentrations

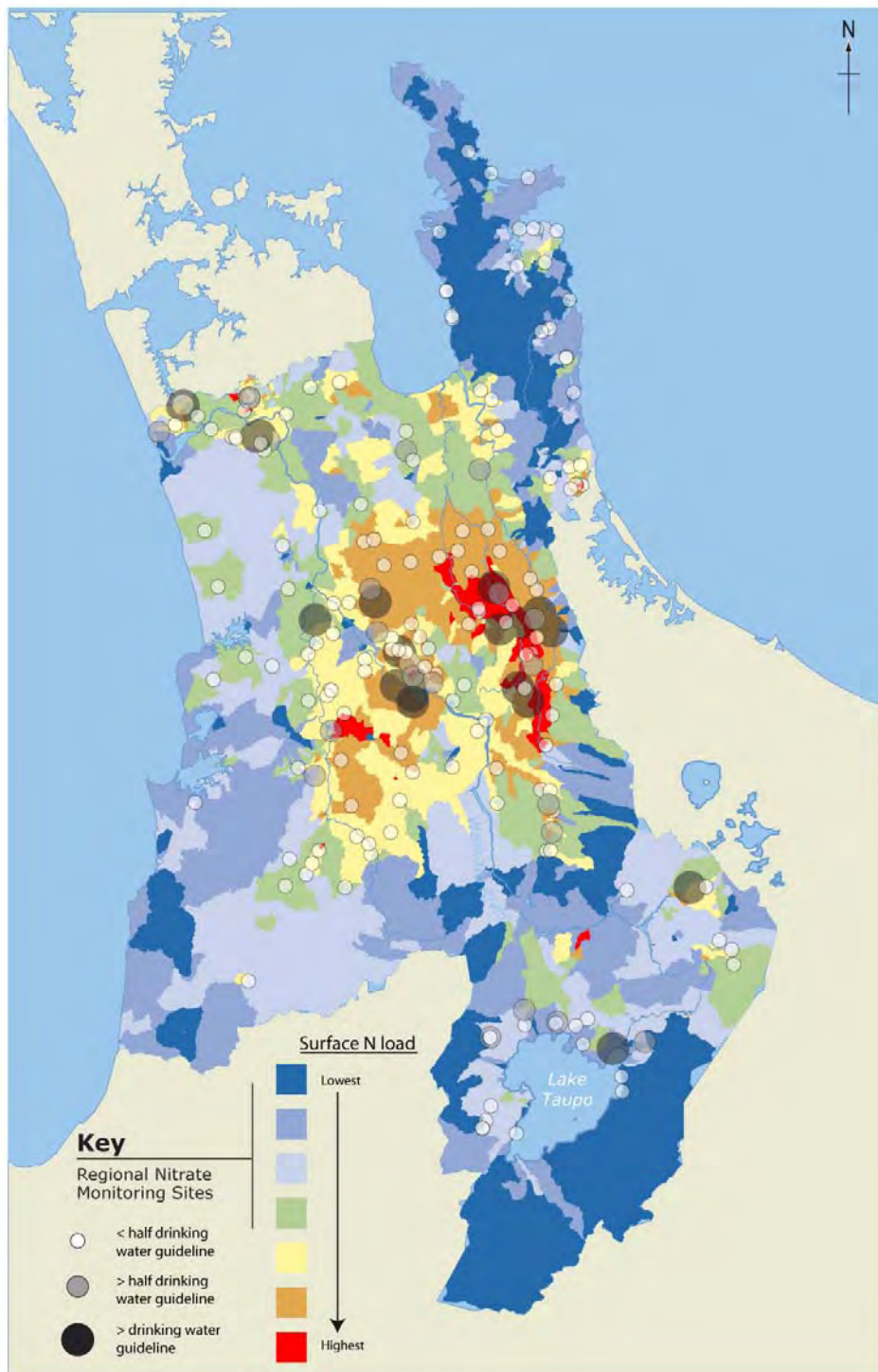


Figure 3: Spatial nitrate leaching and regional nitrate results

3.3 Community network results and summary statistics

Water quality analyses results for the community network are listed in Table 11 and summary statistics are presented in Table 12. Non-detect results are given the half detection value for analysis purposes.

Again there is clear evidence in community well groundwater of land-use impacts on quality. Nitrate exceeded the drinking water standards at 2 supplies (~2.5%) and five wells (~6%) are 'impacted' (> half MAV). About 37 per cent of wells are land-use 'influenced' and just over half the wells (45 or ~55%) have nitrate at 'ambient' concentrations. Many of these are due to the existence of anaerobic conditions. The greater proportion of wells with 'ambient' concentrations is likely to reflect the more objective nature of this dataset and some local buffering of farming influence being on school grounds.

Table 11: Community groundwater quality network monitoring results (concentrations in g m⁻³, conductivity in mS m⁻¹, (D) indicates dissolved rather than total concentrations).

LOC KEY	Name	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Con d
60-13	Coroglen School	23/11/2010	146	0.0054	0.0065	0.082	3.9	< .00005	< .000053	14.6	25.9
60-236	Manaia School	22/11/2010	72	< .001	0.021	0.03	8.9	< .00005	< .000053	17.3	14.08
60-260	Tapu School	22/11/2010	230	< .001	0.0013	0.26	65	< .00005	< .000053	33	34.5
							<				
60-290	Opoutere School	24/11/2010	54	0.0022	0.0022	0.0124	.053	< .00005	< .000053	15.9	15.94
60-314	Puriri Valley School	22/11/2010	44	< .001	0.005	0.0131	8.9	< .00005	< .000053	17.9	13.17
60-393	Hikuai School	24/11/2010	19.6	< .001	< .0011	0.011	1.96	< .00005	< .000053	12.7	7.16
60-478	Matatoki School	22/11/2010	35	< .001	0.0044	0.029	9.7	< .00005	0.000086	21	15.91
61-1255	Pukekawa School	16/11/2010	61	< .001	0.0021	0.0178	9.2	0.00008	0.000108	20	19.4
61-1679	Naike School	24/11/2010	97	< .001	0.0031	0.0162	40	< .00005	0.000171	14.6	25.6
61-1680	Waikaretu School	24/11/2010	192	< .001	< .0011	0.029	82	< .00005	< .000053	58	15.7
61-1727	Aka Aka Primary School	16/11/2010	84	< .001	< .0011	0.053	16	< .00005	< .000053	30	25
61-1728	Mercer School	14/12/2010	97	< .001	< .0011	0.026	19.9	< .00005	< .000053	23	28.6
61-1729	Otaua Primary School	16/11/2010	115	0.0011	< .0011	0.0198	17.5	< .00005	< .000053	55	40.6
61-1730	Mangatangi School	14/12/2010	46	< .001	0.0136	0.016	5.6	< .00005	0.00083	17.3	15.3
61-1731	Mangatawhiri School	30/11/2010	17.4	< .001	< .0011	0.0153	1.36	< .00005	< .000053	15.9	10.1
61-182	Onewhero School	16/11/2010	65	< .001	< .0011	0.0149	8	< .00005	< .000053	18	21
61-761	Harrisville School	16/11/2010	11.5	< .001	< .0011	0.0189	2	< .00005	< .000053	13.7	13.4
63-390	Kaihere School	22/11/2010	20	< .001	0.0017	0.0135	2.9	< .00005	< .000053	12.2	9.4
63-392	Waimata School	23/11/2010	72	0.0028	0.0031	0.0188	8.6	< .00005	< .000053	9.1	16.5
64-32	Hoe-O-Tainui School	22/11/2010	22	< .001	< .0011	0.0091	2.1	< .00005	< .000053	19.4	12.1
64-456	Kiwitahi School	17/11/2010	35	< .001	< .0011	0.0156	3.6	< .00005	< .000053	14.4	12.6
64-500	Manawaru School	17/11/2010	7.1	< .001	< .0011	0.0136	6.9	0.00007	0.000066	12.2	17
64-744	Tauhei School	30/11/2010	24	< .001	< .0011	0.064	2.5	< .00005	< .000053	40	22.9
64-751	Te Puinga School	29/11/2010	32	0.003	0.0064	0.0085	20	0.00012	0.000129	64	53.2
64-807	Walton School	17/11/2010	56	< .001	0.0038	0.0139	4	< .00005	< .000053	8.3	14
64-879	Hinuera School	23/11/2010	30	< .001	0.025	0.0166	6.8	< .00005	0.00047	8.1	13.3
64-880	Kereone School	29/11/2010	21	< .001	< .0011	0.0143	3.3	< .00005	< .000053	11.8	11.8
64-881	Mangateparu School	22/11/2010	15.6	< .001	< .0011	0.0167	1.31	0.00006	0.000068	11.4	9.6
64-883	Richmond Downs School	17/11/2010	59	< .001	< .0011	0.0124	5.5	< .00005	< .000053	7.7	13.8
64-884	Tatuanui School	17/11/2010	22	< .001	< .0011	0.068	10.5	< .00005	< .000053	12.4	21.3
64-885	Waihou School	23/11/2010	25	< .001	0.0012	0.109	7.8	< .00005	< .000053	42	25.7
64-990	Springdale Primary School	30/11/2010	16.7	< .001	< .0011	0.0173	50	0.00095	0.001	131	73.8
64-993	Elstow Primary School	23/11/2010	260	0.0077	0.0097	0.55	10.3	< .00005	< .000053	17.9	52.5
64-994	Ngarua Primary School	17/11/2010	26	< .001	< .0011	0.044	14	< .00005	< .000053	23	25
64-995	Wardville Primary School	23/11/2010	7.5	< .001	0.021	0.0143	41	0.00038	0.00126	22	48.8

LOC KEY	Name	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Con d
64-996	Te Poi Primary School	23/11/2010	19.8	< .001	< .0011	0.0126	2.1	< .00005	< .000053	6.7	8.1
65-285	Ngutunui Primary School	16/11/2010	52	< .001	< .0011	0.0079	9.1	< .00005	< .000053	6.5	12.6
67-565	Okoroire School	17/11/2010	29	< .001	< .0011	0.0134	2.2	< .00005	< .000053	5.2	6.32
67-566	Tapapa School	17/11/2010	24	< .001	< .0011	0.021	3.4	< .00005	< .000053	9.5	10.7
67-567	Te Waotu School	17/11/2010	31	< .001	< .0011	0.0127	4	< .00005	< .000053	7.1	4.22
67-602	Puketurua Primary School	17/11/2010	27	< .001	< .0011	0.0103	5.6	< .00005	< .000053	14.3	13.8
68-1000	Kuratau Primary School	25/11/2010	15.8	< .001	< .0011	< .0053	3.8	< .00005	< .000053	3.4	6.73
69-1349	Horsham Downs School	30/11/2010	28	< .001	< .0011	0.0126	3.1	< .00005	< .000053	15.4	13
69-1446	Ohinewai School	24/11/2010	37	0.0033	0.0061	0.064	3.8	< .00005	< .000053	22	14.8
69-1809	Tauwhare School	10/12/2010	21	< .001	0.0069	0.011	9.5	< .00005	0.000072	6.7	13
69-1816	Te Mata School	25/11/2010	124	< .001	< .0011	0.025	32	< .00005	< .000053	18.3	29.3
69-1897	Waikokowai School	29/11/2010	135	< .001	0.0018	0.34	8	< .00005	< .000053	21	32.7
69-1902	Waiterimu School	22/11/2010	17.2	< .001	< .0011	0.0102	3.4	< .00005	< .000053	20	15.3
69-2071	Glen Massey School	24/11/2010	27	< .001	< .0011	0.0139	3.4	< .00005	< .000053	13.2	10.8
69-2072	Matangi School	10/12/2010	35	0.0021	0.0058	0.24	11	< .00005	0.000081	17.8	19
69-2072	Matangi School	22/12/2010	28	< .001	< .0011	0.31	10.4	< .00005	< .000053	10	14.2
69-2073	Te Kura O Ngati Haua School	17/11/2010	140	< .001	< .0011	0.031	28	< .00005	< .000053	22	33.3
69-2074	Orini School	22/11/2010	24	< .001	< .0011	0.0189	3.4	< .00005	< .000053	18	13
69-2075	Rotokauri School	29/11/2010	34	0.0011	0.0012	0.0142	3.9	< .00005	< .000053	18.2	13.2
69-2076	Te Akau School	24/11/2010	230	< .001	< .0011	0.079	93	< .00005	< .000053	34	59
69-2077	Te Kowhai School	25/11/2010	42	< .001	< .0011	0.028	13.2	< .00005	0.000063	32	26.7
69-2079	Waitetuna School	25/11/2010	51	< .001	< .0011	8	13.2	< .00005	< .000053	310	37.1
69-2080	Whatawhata School	25/11/2010	18.1	< .001	< .0011	0.0193	6.5	< .00005	< .000053	17	17
69-2081	Whitikahu School	22/11/2010	110	0.0013	0.0029	0.52	11.7	< .00005	< .000053	41	34
69-2187	Horotiu School	25/11/2010	40	0.0016	0.0024	0.04	7.1	< .00005	< .000053	11	12.7
69-912	Gordonton School	22/11/2010	26	< .001	< .0011	0.0063	21	< .00005	< .000053	38	42
70-1156	Hora Hora School	18/11/2010	71	< .001	< .0011	0.0115	9.1	< .00005	< .000053	8.4	12.16
70-1157	Karapiro School	30/11/2010	33	< .001	< .0011	0.0136	6.6	< .00005	< .000053	9.7	11.61
70-1158	Ngahinapouri School	25/11/2010	9.5	< .001	< .0011	0.0082	15.6	< .00005	< .000053	19	20.8
70-1159	Parawera School	16/11/2010	26	< .001	< .0011	0.012	3.2	< .00005	< .000053	9.9	10.9
70-1161	Rukuhia School	10/12/2010	75	< .001	< .0011	0.0105	7.2	< .00005	< .000053	12.4	19.4
70-1162	Whitehall School	30/11/2010	22	< .001	< .0011	0.0115	1.68	< .00005	< .000053	7.5	7.55
70-1164	Puahue School	16/11/2010	22	< .001	0.0012	0.0132	1.74	< .00005	< .000053	7.2	5.53
70-1187	Capernwray Bible College	30/11/2010	24	< .001	< .0011	0.0183	4.4	< .00005	< .000053	14	11.44
70-1231	Goodwood School	15/12/2010	31	< .001	< .0011	0.034	13.1	< .00005	< .000053	14.4	20.7
70-453	Hautapu School	10/12/2010	43	< .001	< .0011	0.021	21	< .00005	< .000053	22	30.8
70-778	Paterangi School	30/11/2010	46	< .001	< .0011	0.0104	4.9	< .00005	< .000053	10.3	12.48
70-794	Pokuru School	16/11/2010	22	< .001	0.0013	0.0121	1.76	< .00005	< .000053	6.4	5.3
70-804	Pukeatua School	17/11/2010	28	< .001	< .0011	0.0165	3.3	< .00005	< .000053	10.3	4.93

LOC KEY	Name	Date	Alkalinity	As (D)	As	B	Ca	Cd (D)	Cd	Cl	Con d
70-951	Te Miro School	14/12/2010	46	< .001	< .0011	0.0055	8.2	< .00005	< .000053	9.9	12.2
70-952	Te Pahu School	30/11/2010	63	< .001	< .0011	0.0116	7	< .00005	< .000053	11.9	15.76
71-60	Kinohaku School	16/11/2010	172	0.0012	0.0047	0.42	16.4	< .00005	< .000053	37	32.3
72-1857	Te Kohanga Primary School	16/11/2010	102	< .001	< .0011	0.0186	14.3	< .00005	< .000053	23	26.4
72-640	Te Puru School	22/11/2010	133	0.0014	0.0031	0.128	250	< .00005	< .000053	600	308
72-739	Te Uku School	25/11/2010	173	< .001	< .0011	0.071	33	< .00005	< .000053	18.5	11.6
68-794	Waitahanui School	25/11/2010	44	0.0055	0.0057	0.0124	2.2	< .00005	< .000053	2.3	10.32

LOC KEY	Name	Date	Cu	F	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na
60-13	Coroglen School	23/11/2010	< .00053	0.25	< .02	< .021	< 1	11	1.46	0.28	0.012	0.0131	69
60-236	Manaia School	22/11/2010	0.0021	0.19	1.65	27	36	48	3	6.2	0.42	0.45	16.9
60-260	Tapu School	22/11/2010	0.0021	0.09	< .02	0.049	30	210	3.8	12.7	0.146	0.157	51
60-290	Opoutere School	24/11/2010	< .00053	0.07	< .02	0.024	15.9	< 1	4	< .021	0.001	0.00156	33
60-314	Puriri Valley School	22/11/2010	0.023	< .05	< .02	2.5	15.2	36	2.2	3.3	0.134	0.154	15.7
60-393	Hikuai School	24/11/2010	0.00104	< .05	< .02	< .021	37	9	4	0.99	0.0135	0.0146	12.5
60-478	Matatoki School	22/11/2010	0.0038	0.06	< .02	37	39	36	1.64	2.9	0.084	0.122	20
61-1255	Pukekawa School	16/11/2010	0.0151	0.05	< .02	3.3	22	50	2.8	6.6	0.006	0.0082	16.3
61-1679	Naike School	24/11/2010	7.3	0.1	< .02	1.83	15	104	1.21	1.36	0.006	0.0086	11.1
61-1680	Waikaretu School	24/11/2010	0.00087	0.08	< .02	2.4	16	230	1.32	5.3	0.0144	0.0167	29
61-1727	Aka Aka Primary School	16/11/2010	< .00053	0.11	0.03	0.035	< 1	56	3.9	3.9	0.021	0.022	28
61-1728	Mercer School	14/12/2010	< .00053	0.11	0.03	0.07	23	89	5.3	9.5	0.0021	0.0022	23
61-1729	Otaua Primary School	16/11/2010	< .00053	0.17	0.03	0.049	5.6	125	3.1	19.8	0.099	0.098	30
61-1730	Mangatangi School	14/12/2010	0.0127	0.07	0.03	37	36	29	4.9	3.6	0.58	0.74	16.8
61-1731	Mangatawhiri School	30/11/2010	0.0148	0.07	< .02	0.39	25	7.2	3.4	0.93	0.0065	0.0069	15
61-182	Onewhero School	16/11/2010	0.00198	0.06	< .02	0.195	1.7	66	1.9	11.2	0.0009	0.00111	14.8
61-761	Harrisville School	16/11/2010	0.00085	< .05	< .02	0.027	12.3	24	0.81	4.7	0.0008	0.0021	14.2
63-390	Kaihere School	22/11/2010	0.0149	< .05	< .02	51	45	15.7	2.5	2.1	0.0163	0.112	12.5
63-392	Waimata School	23/11/2010	0.00146	0.1	0.06	0.098	6.7	50	3.3	7	0.125	0.151	13.4
64-32	Hoe-O-Tainui School	22/11/2010	0.026	< .05	< .02	0.91	40	14.3	0.98	2.2	0.023	0.025	17.9
64-456	Kiwitahi School	17/11/2010	0.0006	0.07	< .02	1.3	29	24	4.8	3.6	0.0027	0.0031	12.7
64-500	Manawaru School	17/11/2010	< .00053	< .05	< .02	0.4	14.5	35	6.6	4.4	0.02	0.02	11.2
64-744	Tauhei School	30/11/2010	0.0127	< .05	< .02	3.2	37	18	5	2.9	0.0061	0.0089	34
64-751	Te Puninga School	29/11/2010	0.00064	0.05	2.2	5	15	125	30	17.9	0.74	0.74	31
64-807	Walton School	17/11/2010	0.021	0.07	0.85	19.3	22	31	4.7	5	0.048	0.076	13
64-879	Hinuera School	23/11/2010	0.034	< .05	< .02	58	28	30	6.4	3.3	0.097	0.15	11.7
64-880	Kereone School	29/11/2010	0.0098	< .05	< .02	0.22	21	16.7	5.1	2.1	0.0013	0.00132	12.7

LOC KEY	Name	Date	Cu	F	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na
64-881	Mangateparu School	22/11/2010	0.0109	0.05	< .02	0.089	37	7.4	4	1	0.0037	0.004	13.1
64-883	Richmond Downs School	17/11/2010	0.0055	0.1	0.05	1	28	34	2.6	4.9	0.005	0.0058	15.7
64-884	Tatuanui School	17/11/2010	0.0023	0.06	< .02	0.021	18.2	55	6.1	7	0.0039	0.0037	15.4
64-885	Waihou School	23/11/2010	0.0141	< .05	< .02	1.47	14.6	39	6.6	4.7	0.0052	0.094	27
64-990	Springdale Primary School	30/11/2010	0.037	< .05	0.08	3.1	38	220	15.8	24	0.24	0.24	34
64-993	Elstow Primary School	23/11/2010	0.00069	0.26	0.66	2.7	46	62	5.5	8.8	0.27	0.28	97
64-994	Ngarua Primary School	17/11/2010	0.0023	< .05	< .02	< .021	14.9	67	7	7.8	0.0031	0.0033	15.8
64-995	Wardville Primary School	23/11/2010	0.028	0.09	0.04	16.8	84	210	9.6	26	0.56	0.66	16.8
64-996	Te Poi Primary School	23/11/2010	0.0073	< .05	< .02	0.027	19.4	9.4	4.5	1.01	0.0009	0.0008	9.7
65-285	Ngutunui Primary School	16/11/2010	0.0146	< .05	< .02	1.96	16	42	1.45	4.6	0.0039	0.0054	7.4
67-565	Okoroire School	17/11/2010	0.0049	0.08	< .02	< .021	21	11.9	3.2	1.57	< .0005	0.00076	9.6
67-566	Tapapa School	17/11/2010	0.0072	0.06	< .02	0.52	21	16.2	5.3	1.85	0.0047	0.0059	12.1
67-567	Te Waotu School	17/11/2010	0.00061	< .05	< .02	< .021	22	19.7	3.9	2.3	< .0005	0.00087	8.4
67-602	Puketurua Primary School	17/11/2010	0.0099	0.06	< .02	0.049	19.8	26	4.8	2.9	< .0005	0.0006	12.3
68-1000	Kuratau Primary School	25/11/2010	0.00098	< .05	< .02	< .021	6.3	15	2.8	1.33	< .0005	< .00053	5.1
69-1349	Horsham Downs School	30/11/2010	< .00053	0.06	< .02	< .021	22	14.4	4	1.61	0.0012	0.0008	19.9
69-1446	Ohinewai School	24/11/2010	0.00195	0.09	1.83	4.3	29	18	3.5	2.1	0.153	0.168	18.9
69-1809	Tauwhare School	10/12/2010	0.0035	0.05	0.12	48	13	39	2.5	3.7	0.135	0.31	8.8
69-1816	Te Mata School	25/11/2010	< .00053	0.11	< .02	0.63	5.4	113	2.2	8.1	0.19	0.21	15.5
69-1897	Waikokowai School	29/11/2010	0.0031	0.13	< .02	13.3	2.6	39	3.8	4.6	0.0112	0.066	63
69-1902	Waiterimu School	22/11/2010	0.024	< .05	< .02	0.87	41	18.6	5.1	2.4	0.006	0.0063	18.4
69-2071	Glen Massey School	24/11/2010	0.023	0.06	< .02	1.97	24	16.6	3.2	1.98	0.0013	0.0034	13.4
69-2072	Matangi School	10/12/2010	0.028	0.52	0.17	1.55	4.8	40	3.1	3	0.0038	0.04	18.9
69-2072	Matangi School	22/12/2010	0.00193	< .05	< .02	0.189	15.9	41	2.4	3.7	0.0005	0.0058	9.9
69-2073	Te Kura O Ngati Haua School	17/11/2010	< .00053	0.1	< .02	0.079	14.7	108	1.29	9.3	0.028	0.028	28
69-2074	Orini School	22/11/2010	0.0091	< .05	< .02	1.02	38	15.3	3.5	1.62	0.0027	0.0039	15.7
69-2075	Rotokauri School	29/11/2010	< .00053	0.08	< .02	0.035	20	16.3	4.5	1.59	0.001	0.0009	17.6
69-2076	Te Akau School	24/11/2010	0.00065	0.14	< .02	< .021	22	260	1.54	6	0.0024	0.0063	28
69-2077	Te Kowhai School	25/11/2010	0.00064	0.05	< .02	0.32	23	65	7.1	7.8	1.32	1.36	21
69-2079	Waitetuna School	25/11/2010	< .00053	3.4	0.13	0.17	< 1	36	1.26	0.82	0.058	0.066	210
69-2080	Whatawhata School	25/11/2010	0.0129	0.06	< .02	0.027	3.6	36	4.6	4.8	0.0028	0.0024	16
69-2081	Whitikahu School	22/11/2010	0.0141	0.08	2.9	12.8	64	69	7.7	9.8	0.84	0.77	34
69-2187	Horotiu School	25/11/2010	0.0012	0.06	< .02	0.23	10.9	31	5.8	3.1	0.0036	0.016	13.7
69-912	Gordonton School	22/11/2010	0.0093	< .05	< .02	1.1	36	183	6.2	31	0.0103	0.0115	15.8
70-1156	Hora Hora School	18/11/2010	< .00053	< .05	< .02	0.093	8	53	3.5	7.5	0.0015	0.0022	11.4
70-1157	Karapiro School	30/11/2010	0.0107	0.11	0.02	1.4	9.9	24	4	1.92	0.0025	0.0036	11.1

LOC KEY	Name	Date	Cu	F	Fe (D)	Fe	Free CO ₂	Hardness	K	Mg	Mn (D)	Mn	Na
70-1158	Ngahinapouri School	25/11/2010	0.001	< .05	< .02	< .021	6.3	63	3.6	5.9	0.0019	0.00181	8.9
70-1159	Parawera School	16/11/2010	0.0085	< .05	< .02	0.128	17.5	14.6	5.7	1.6	0.0007	0.00079	11.4
70-1161	Rukuhia School	10/12/2010	0.00182	< .05	0.07	0.16	63	38	7.3	4.7	0.064	0.064	22
70-1162	Whitehall School	30/11/2010	< .00053	< .05	< .02	0.071	9.9	6.9	3.1	0.67	< .0005	< .00053	10.4
70-1164	Puahue School	16/11/2010	0.00073	< .05	0.02	0.191	20	9.7	3.8	1.29	0.0025	0.0022	9.8
70-1187	Capernwray Bible College	30/11/2010	< .00053	< .05	< .02	0.59	17.2	20	4.3	2.3	0.0025	0.0035	13.4
70-1231	Goodwood School	15/12/2010	< .00053	< .05	< .02	< .021	15	60	4.3	6.5	< .0005	< .00053	12.9
70-453	Hautapu School	10/12/2010	0.0025	< .05	< .02	< .021	30	92	6.7	9.7	< .0005	< .00053	18.5
70-778	Paterangi School	30/11/2010	< .00053	0.07	0.04	0.106	10.3	19.8	3.9	1.82	0.0035	0.0037	16.2
70-794	Pokuru School	16/11/2010	0.0024	< .05	< .02	0.31	7.7	8.3	3.7	0.95	0.0008	0.00194	9.1
70-804	Pukeatua School	17/11/2010	0.0021	< .05	< .02	< .021	22	15.3	4.7	1.69	0.0007	0.0026	10.4
70-951	Te Miro School	14/12/2010	< .00053	0.05	< .02	14.1	12.1	32	2.8	2.7	0.24	0.3	10.5
70-952	Te Pahu School	30/11/2010	< .00053	0.09	0.04	0.42	12.4	45	3.9	6.7	0.11	0.113	13.2
71-60	Kinohaku School	16/11/2010	0.0024	0.29	< .02	1.33	14.9	59	1.12	4.3	0.35	0.35	80
72-1857	Te Kohanga Primary School	16/11/2010	< .00053	0.07	0.04	0.194	6.4	90	2.7	13.1	0.0017	0.00182	18.9
72-640	Te Puru School	22/11/2010	0.00069	0.13	< .02	2.3	10.3	710	3.3	21	0.28	0.29	330
72-739	Te Uku School	25/11/2010	0.00096	0.08	0.02	0.32	3.6	133	3.1	12.7	0.085	0.098	25
68-794	Waitahanui School	25/11/2010	< .00053	0.58	< .02	< .021	< 1	7.5	0.151	0.51	0.0188	0.022	20

LOC KEY	Name	Date	NH ₄	NO ₃ -N	pH	SO ₄	T.D. Solids	Temperature	Zn (D)	Zn
60-13	Coroglen School	23/11/2010	0.024	< .05	8.8	3	220	18.6	0.0061	0.008
60-236	Manaia School	22/11/2010	0.26	< .05	6.6	0.8	138	16.3	< .001	0.0016
60-260	Tapu School	22/11/2010	< .01	2.4	7.2	43	420	19.4	0.0067	0.0075
60-290	Opoutere School	24/11/2010	< .01	< .05	6.8	3.8	112	17.6	< .001	< .0011
60-314	Puriri Valley School	22/11/2010	< .01	0.78	6.8	4.8	111	18.2	0.142	0.156
60-393	Hikuai School	24/11/2010	< .01	1.33	6	2.2	66	14.7	0.01	0.0109
60-478	Matatoki School	22/11/2010	0.063	0.11	6.3	18.9	125	17.7	0.0057	0.022
61-1255	Pukekawa School	16/11/2010	< .01	0.47	6.7	3	130	15	0.22	0.31
61-1679	Naike School	24/11/2010	< .01	1.62	7.1	4.7	172	15.6	0.42	1.25
61-1680	Waikaretu School	24/11/2010	< .01	< .05	7.4	18.6	380		0.0019	0.0064
61-1727	Aka Aka Primary School	16/11/2010	0.31	< .05	8.3	1.8	179	21.6	0.0033	0.0038
61-1728	Mercer School	14/12/2010	< .01	1.93	6.9	4.6	195	18.1	0.116	0.116
61-1729	Otaua Primary School	16/11/2010	0.019	< .05	7.6	7.8	270	16.7	0.0049	0.0067
61-1730	Mangatangi School	14/12/2010	< .01	< .05	6.4	2.5	104	18.6	0.62	5.6
61-1731	Mangatawhiri School	30/11/2010	< .01	0.45	6.2	3.8	68	19.4	0.084	0.072
61-182	Onewhero School	16/11/2010	< .01	3.4	7.9	2.4	143	14.8	0.0133	0.0193

LOC KEY	Name	Date	NH ₄	NO ₃ -N	pH	SO ₄	T.D. Solids	Temperature	Zn (D)	Zn
61-761	Harrisville School	16/11/2010	< .01	7.5	6.3	1.8	91	16.3	0.08	0.19
63-390	Kaihere School	22/11/2010	< .01	0.62	6	3.1	64	19.5	0.025	0.078
63-392	Waimata School	23/11/2010	< .01	0.1	7.3	2.6	117	18	0.66	0.66
64-32	Hoe-O-Tainui School	22/11/2010	< .01	0.83	6	3.2	82	16.4	0.079	0.076
64-456	Kiwitahi School	17/11/2010	< .01	0.14	6.4	2.6	85	17.6	0.0026	0.0062
64-500	Manawaru School	17/11/2010	< .01	3	6	40	117	16.5	0.0071	0.0047
64-744	Tauhei School	30/11/2010	0.01	1.87	6.1	13.4	154	18.5	0.0191	0.026
64-751	Te Puinga School	29/11/2010	0.25	1.61	6.6	103	360	17.6	0.0145	0.0151
64-807	Walton School	17/11/2010	< .01	< .05	6.7	1.7	94	16.9	0.0033	0.058
64-879	Hinuera School	23/11/2010	0.021	0.74	6.3	15.4	89	15.9	0.036	0.42
64-880	Kereone School	29/11/2010	< .01	3.6	6.3	2.1	79	19.8	0.042	0.039
64-881	Mangateparu School	22/11/2010	< .01	2.1	5.9	3.7	66	17	0.64	0.61
64-883	Richmond Downs School	17/11/2010	< .01	0.12	6.6	1.6	97	17.2	0.038	0.044
64-884	Tatuanui School	17/11/2010	< .01	4.1	6.4	46	147	18.3	0.0084	0.0091
64-885	Waihou School	23/11/2010	< .01	3.3	6.5	15.6	174	18.2	0.09	0.113
64-990	Springdale Primary School	30/11/2010	0.61	24	5.9	33	500	15.6	0.38	0.38
64-993	Elstow Primary School	23/11/2010	0.48	< .05	7	< .5	350	24.4	0.0029	0.0053
64-994	Ngarua Primary School	17/11/2010	0.035	8	6.5	27	172	18.6	0.016	0.0169
64-995	Wardville Primary School	23/11/2010	0.012	4.4	5.2	180	340	16.1	0.8	1.26
64-996	Te Poi Primary School	23/11/2010	< .01	1.74	6.3	2.1	56	17.5	0.045	0.046
65-285	Ngutunui Primary School	16/11/2010	< .01	0.23	6.8	1.1	85	15.2	0.0106	0.0137
67-565	Okoroire School	17/11/2010	< .01	0.14	6.4	1.6	53	17	0.0083	0.0054
67-566	Tapapa School	17/11/2010	< .01	2.7	6.4	1.8	72	15.1	0.034	0.047
67-567	Te Waotu School	17/11/2010	< .01	1.17	6.4	2.3	66	14.6	0.6	0.61
67-602	Puketurua Primary School	17/11/2010	< .01	3.4	6.4	2.8	93	14.6	0.196	0.196
68-1000	Kuratau Primary School	25/11/2010	< .01	2	6.7	3.3	46	14.2	0.0012	0.0014
69-1349	Horsham Downs School	30/11/2010	< .01	1.23	6.4	5.3	87	17.9	0.026	0.0167
69-1446	Ohinewai School	24/11/2010	0.25	< .05	6.4	1.8	99	18.9	0.003	0.0043
69-1809	Tauwhare School	10/12/2010	0.056	0.72	6.5	24	87	15.5	< .001	0.0098
69-1816	Te Mata School	25/11/2010	0.018	< .05	7.7	1.8	197	16	0.0136	0.163
69-1897	Waikokowai School	29/11/2010	0.71	< .05	8	5.9	220	16.6	< .001	0.025
69-1902	Waiterimu School	22/11/2010	< .01	5.6	5.9	1.5	105	16.8	0.081	0.078
69-2071	Glen Massey School	24/11/2010	< .01	0.5	6.4	3.4	73	15.5	0.0138	0.026
69-2072	Matangi School	10/12/2010	< .01	0.17	7.2	22	128	19	0.037	0.063
69-2072	Matangi School	22/12/2010	< .01	3.2	6.6	10.3	95	16.1	0.0102	0.0119
69-2073	Te Kura O Ngati Haua School	17/11/2010	< .01	< .05	7.3	4	230	18.4	1.15	1.25

LOC KEY	Name	Date	NH ₄	NO ₃ -N	pH	SO ₄	T.D. Solids	Temperature	Zn (D)	Zn
69-2074	Orini School	22/11/2010	< .01	1.86	6.1	2.6	89	17.6	0.0117	0.0146
69-2075	Rotokauri School	29/11/2010	< .01	0.08	6.5	2.8	89	17.7	0.0028	0.0069
69-2076	Te Akau School	24/11/2010	< .01	1.24	7.3	34	400	16.7	0.0017	0.0032
69-2077	Te Kowhai School	25/11/2010	< .01	7.9	6.6	10.4	186	15.8	0.0022	0.0061
69-2079	Waitetuna School	25/11/2010	0.27	< .05	8.8	< .5	780	17	< .001	0.0012
69-2080	Whatawhata School	25/11/2010	< .01	1.64	7	27	118	16.7	0.0071	0.0088
69-2081	Whitikahu School	22/11/2010	< .01	< .05	6.5	2.4	250	17.4	0.044	0.111
69-2187	Horotiu School	25/11/2010	< .01	1.82	6.9	4.6	95	18.2	0.0179	0.032
69-912	Gordonton School	22/11/2010	0.072	30	6.2	31	330	16	0.04	0.044
70-1156	Hora Hora School	18/11/2010	< .01	0.32	7.2	2	113	17.7	0.17	0.2
70-1157	Karapiro School	30/11/2010	< .01	1.73	6.8	1.7	78	17.3	0.145	0.173
70-1158	Ngahinapouri School	25/11/2010	< .01	10.6	6.5	12.8	141	15.8	0.0045	0.0048
70-1159	Parawera School	16/11/2010	< .01	1.91	6.5	1.7	73	14.6	0.059	0.063
70-1161	Rukuhia School	10/12/2010	< .01	< .05	6.4	3.4	130	17.8	0.0091	0.0116
70-1162	Whitehall School	30/11/2010	< .01	0.8	6.6	1.7	52	17.7	0.113	0.105
70-1164	Puahue School	16/11/2010	< .01	0.86	6.3	2.2	55	15.3	0.072	0.075
70-1187	Capernwray Bible College	30/11/2010	< .01	2.9	6.4	1.7	82	15.4	0.025	0.029
70-1231	Goodwood School	15/12/2010	< .01	5.1	6.6	22	143	17.4	< .001	< .0011
70-453	Hautapu School	10/12/2010	< .01	8.2	6.5	35	210	17.7	0.0036	0.0046
70-778	Paterangi School	30/11/2010	< .01	0.08	7	1.2	83	18.3	0.5	0.52
70-794	Pokuru School	16/11/2010	< .01	0.12	6.8	1.6	49	16.1	0.0061	0.0064
70-804	Pukeatua School	17/11/2010	< .01	0.37	6.4	1.9	65	15.1	0.03	0.03
70-951	Te Miro School	14/12/2010	0.173	< .05	6.9	< .5	82	16.6	0.0024	0.0032
70-952	Te Pahu School	30/11/2010	< .01	0.07	7	1.3	108	16.5	0.059	0.071
71-60	Kinohaku School	16/11/2010	0.032	2.6	7.4	21	330	16.5	0.17	0.25
72-1857	Te Kohanga Primary School	16/11/2010	< .01	0.64	7.5	4.1	188	17.2	0.77	0.86
72-640	Te Puru School	22/11/2010	0.091	< .05	7.4	510	2100	20.7	< .001	< .0011
72-739	Te Uku School	25/11/2010	0.67	< .05	8	< .5	250	18.4	< .001	0.0059
68-794	Waitahanui School	25/11/2010	< .01	< .05	8.8	7.2	69	12	< .001	0.0106

Table 12: General groundwater quality statistics for the 81 community well network (concentrations in g m⁻³, conductivity in mS m⁻¹, (D) indicates dissolved rather than total concentrations).

Determinand	Mean	Median	Min	Max	St dev	Skew	Non-detect
Alkalinity	57.89	35	7.1	260	55.07	1.91	0
As	0.0025	0.00055	0.00055	0.025	0.00	3.44	52
B	0.1532	0.0165	0.00026	8	0.89	8.80	1
Ca	15.33	7.2	0.026	250	31.15	5.86	1
Cd	0.000076	0.000026	0.000026	0.00126	0.00	4.78	68
Cl	30.3	15.9	2.3	600	73.80	6.61	0
Cond.	23.4	15.3	4.22	308	34.60	7.18	0
Cu	0.10152	0.0021	0.00026	7.3	0.83	8.77	20
F	0.121	0.06	0.025	3.4	0.38	8.24	31
Fe (D)	0.14	0.01	0.01	2.9	0.49	4.26	57
Fe	4.78	0.32	0.01	58	11.83	3.17	13
Free CO ₂	20.8	17.5	0.5	84	15.25	1.46	4
Hardness	61.5	36	0.5	710	92.12	4.84	1
K	4.32	3.8	0.151	30	3.65	4.81	0
Mg	5.66	3.7	0.01	31	6.01	2.26	1
Mn (D)	0.09	0.006	0.00025	1.32	0.21	3.60	7
Mn	0.11	0.0115	0.0006	1.36	0.23	3.27	4
Na	26.4	15.7	5.1	330	43.02	5.58	0
NH ₄	0.058	0.005	0.005	0.71	0.15	3.27	59
NO ₃ -N	2.26	0.78	0.025	30	4.56	4.40	20
pH	6.8	6.6	5.2	8.8	0.68	1.16	0
SO ₄	18.08	3.2	0.25	510	60.45	7.18	4
TDS	180	112	46	2100	247.65	6.20	0
Temp.	17.1	17	12	24.4	1.79	0.77	0
Zn (D)	0.112	0.016	0.0005	1.15	0.22	2.71	9
Zn	0.208	0.026	0.0005	5.6	0.67	6.94	3

3.4 Comparison of community results with drinking water standards and guidelines

Community groundwater supply quality is compared with drinking water standards and aesthetic guidelines in Table 13. Exceedances of MAVs and half MAVs (inclusive of those exceeding the MAV) are reported for measured determinands of health significance.

It is evident from Table 13 that the most common exceedances in community supplies are for arsenic and manganese and arsenic rather than nitrate. It should be emphasised that these concentrations are from source water sampling and hence measured prior to treatment. Also some school groundwater supplies are used for only non-potable purposes. The relatively lower nitrate exceedances most probably relate to the abandonment of supplies which exceed nitrate MAVs due to the difficulty of its treatment. There is some evidence for this in the community monitoring network history.

Manganese most commonly exceeds the DWS MAV in community supplies. Given it is naturally occurring, its likely source formation can be excluded during well design or treatment is required. It can be readily treated, typically with aeration and filtering.

Arsenic, as previously mentioned is a contaminant of particular concern for human health (Appendix V). Similar to the regional network it exceeds the drinking-water standards in about 4% of wells. Again the exceedences observed are in areas with geothermal influence.

Cadmium has only recently been monitored and has a very low MAV of 0.004 g m⁻³ because it accumulates in the kidneys and has a long biological half life. At one well there was high cadmium and zinc together which may be from the dissolution of galvanised pipes in which it can be an impurity associated with the zinc. Superphosphate is also a potential source for shallow wells where there are sandy soils. Superphosphate is also a potential additional source of fluoride (as well as geothermal).

Table 13: Community network groundwater quality comparison with drinking-water standards

Determinand	>MAV	>half MAV
Arsenic	4 (4.12%)	12 (14.8%)
Boron	1 (1.2%)	1 (1.2%)
Cadmium	0	0
Fluoride	1 (1.2%)	1 (1.2%)
Manganese	6 (7.4%)	13 (16%)
Nitrate	2 (2.5%)	7 (8.6%)
Copper	1 (1.2%)	1 (1.2%)

Comparison of regional groundwater quality with aesthetic guideline values shows that pH most commonly falls outside the ideal range. This is indicative of corrosion concerns relating to typically acidic waters.

Iron and manganese, which typically are elevated together) are common nuisance chemicals causing staining and scaling problems. High concentrations occur in anaerobic and peat influenced waters.

Table 14: Community groundwater quality comparison with aesthetic guideline values (GV)

Determinand	>GV ¹
Ammonia	4 (4.9%)
Chloride	2 (2.5%)
Copper	1 (1.2%)
Hardness	6 (7.4%)
Iron	43 (53%)
Manganese	29 (36%)
pH	60 (74.1%)
Sodium	2 (2.5%)
Sulphate	1 (1.2%)
Zinc	1 (1.2%)

¹ or outside range for pH

3.5 Nitrate trends

There is substantial spatial variation in nitrate concentrations across the region (Figure 3). For example, there is much greater incidence of nitrate exceeding drinking water guidelines in areas with a high proportion of market gardening (Pukekohe) and intensive dairy farming (Hamilton-Mangaonua) than in other areas.

In the Hauraki Plains there is a general trend of decreasing nitrate concentration northward with progressively low-lying, finer and peaty sediments. It is associated with a change from recharge to discharge flow regimes and more reducing groundwater

conditions (i.e. lower redox). Nitrate concentrations are generally highest in shallow, vulnerable aquifers and are lowest in very deep or iron-rich waters.

There are few records available to indicate long-term nitrate trends. Monitoring data from some schools supplies, however, indicate a steady increase at several supplies since the 1950s.

Pressures on groundwater quality are generally increasing as land-use intensifies. The total volume of wastewater consented to discharge to land has increased steadily over the last 10 years (was 540,000 m³ d⁻¹ in 1997).

National surveys of nitrate contamination of New Zealand have found some of the highest nitrate concentrations to be in parts of the Waikato region (Lincoln Environmental, 1998; GNS, 2007).

The 'nitrate' monitoring well network comprises wells listed in Table 15, which are monitored quarterly. These wells have generally been monitored since 1995 although some have longer records. The temporal trends of nitrate-N from these wells are illustrated in the following series of figures.

Table 15: Nitrate groundwater quality network (from doc 1529095)

Well	District	Map Reference	Depth	Age ¹	Land-use
60-12	Coromandel	T11:549-811	9	0.5	urban
61-113	Franklin	R12:831-387	13	4	market garden
61-126	Franklin	R13:607-298	6.09	5	dairy
61-208	Franklin	R12:668-365	18.3	9	drystock ²
61-221	Franklin	R13:872-253	50	22	horticulture
61-59	Franklin	R13:791-285	26.6	11&59	dry stock
63-57	Hauraki	T13:414-204	5	11	dairy
64-108	Matamata-Piako	T14:465-802	23	62	dairy
64-117	Matamata-Piako	T14:565-844	16	7	dairy
64-12	Matamata-Piako	T14:496-863	11.5	7	dairy
64-20	Matamata-Piako	T14:531-738	9	8&46	urban, drystock
64-43	Matamata-Piako	T14:546-712	21.6	50	urban, drystock
64-46	Matamata-Piako	T14:557-780	12	17&43	dairy
64-50	Matamata-Piako	T14:595-797	16.1	15	dairy
64-70	Matamata-Piako	T14:557-901	11.8	27&59	dairy
64-120	Matamata-Piako	T15:510-655	22.2	27	market garden
66-6	Rotorua	U16:943-152	38	30	dairy
67-11	South Waikato	T15:535-620	18.5	62	dairy
67-15	South Waikato	T15:580-510	20	45	drystock ³
69-173	Waikato	S14:151-871	6		dairy
69-365	Waikato	S13:123-022	4.2	due	dairy
69-81	Waikato	S14:982-739	2.25		drystock
70-44	Waipa	S15:244-635	18.3		drystock ²
70-47	Waipa	T15:303-689	4.5	due	dairy
70-56	Waipa	S15:204-660	4.5	7	dairy
70-65	Waipa	S15:030-635	4.3		dairy
70-74	Waipa	S15:040-546	6.71	due	urban
70-76	Waipa	T15:430-574	30	due	dairy
70-21	Waipa	S15:238-661	6.41	5	berry farm
70-22	Waipa	S15:238-660	6.42	5	berry farm

¹age expressed as mean residence time in years (& given with ambiguous ages)

²market garden nearby

³dairy nearby

The following figures show nitrate trends in individual monitoring wells. It can be seen that there is a range of responses to land-use and other factors. Linear trend analysis is reported in Table 16. About 37 per cent (11) of the wells have significantly increasing nitrate concentration trends. Nitrate concentrations have decreased significantly in about 23 per cent (7) of the wells monitored. Some of the temporal trends are clearly not monotonic, such as in wells 64_50, 64_120 and 70_44. These wells show substantial and significant increases followed by similar declines.

Table 16: Mann-Kendall trend analysis of nitrate concentrations

Well	median (g m ⁻³)	n	p-values (%)	trend (g m ⁻³ y ⁻¹)
60-12	0.51	52	<1	0.07
61-113	5.46	62	3.85	0.067
61-126	6.6	59	<1	0.19
61-208	15.5	59	<1	-0.176
61-221	4.42	59	<1	0.117
61-59	14.4	55	<1	0.034
63-57	10.6	58	24	-0.067
64-108	17.6	58	<1	0.22
64-117	13.9	57	5.08	2.9
64-12	4.01	57	<1	0.199
64-20	6.07	58	3.5	0.168
64-43	7.9	57		0
64-46	4.9	59	<1	-0.11
64-50	7.64	59	52.9	-0.03
64-70	0.81	55	<1	-0.067
64-120	7.65	62	37	0.1
66-6	14.4	55	<1	-0.817
67-11	9.38	57	6.32	0.219
67-15	3.72	58	43.39	0.279
69-173	14.3	59	21.37	-0.292
69-365	6.54	59	17.94	-0.081
69-81	6.6	59	<1	-0.29
70-44	15.2	49	78	-0.05
70-47	4.29	59	<1	-0.234
70-56	9.8	55	3.34	0.172
70-65	2.88	58	29.22	0.049
70-74	3.84	59	<1	0.165
70-76	4.09	58	<1	0.098
70-21	9.99	60	90.83	-0.002
70-22	11.7	61	<1	-0.253

It is beyond the scope of this monitoring data report to relate these observed trends to land-use management. Factors such as groundwater age and attenuation mechanisms (denitrification) must be taken into account with land-use history. Contributing 'capture zones' are progressively being delineated for these sites. Ambient nitrate-N concentrations in aerobic conditions reflect vegetation and climate. Native forest and groundcover are likely to leach about 2 kg N ha⁻¹ y⁻¹ (Ledgard, 2000). Effective rainfall is typically greater than 300 mm y⁻¹ and hence a nitrate-N concentration under ambient conditions is unlikely to be significantly greater than 0.6 g m⁻³.

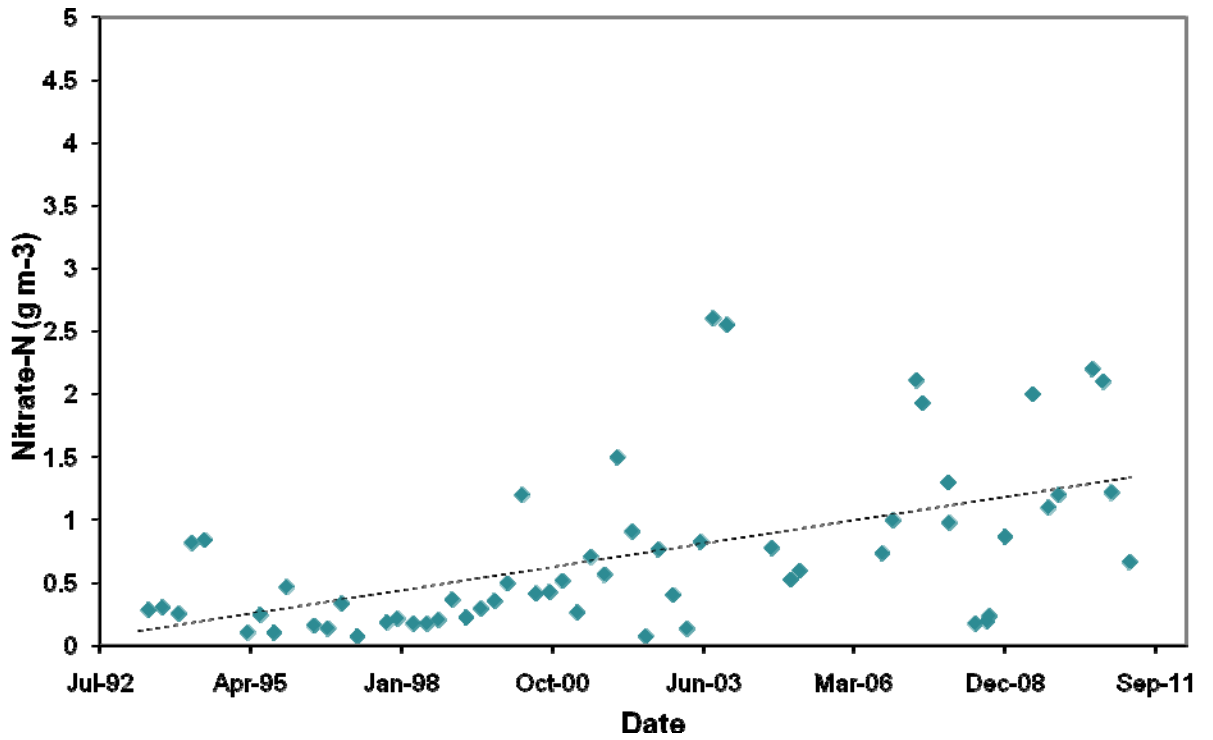


Figure 4: Nitrate concentration trend in well 60_12

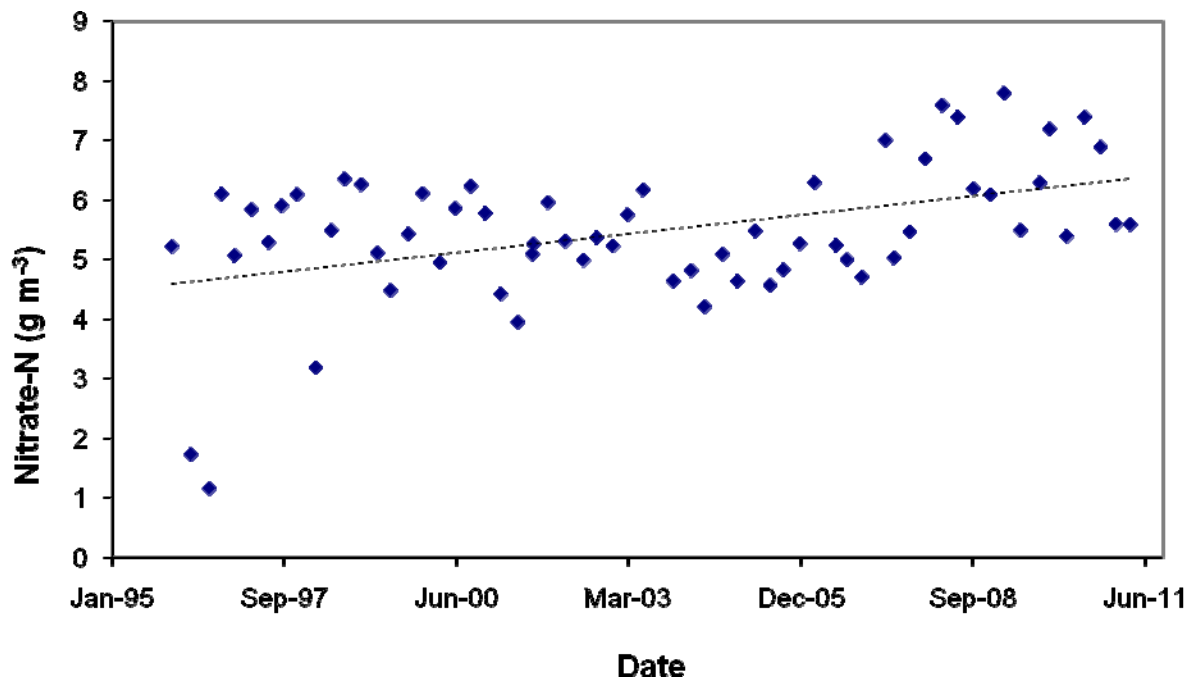


Figure 5: Nitrate concentration trend in well 61_113

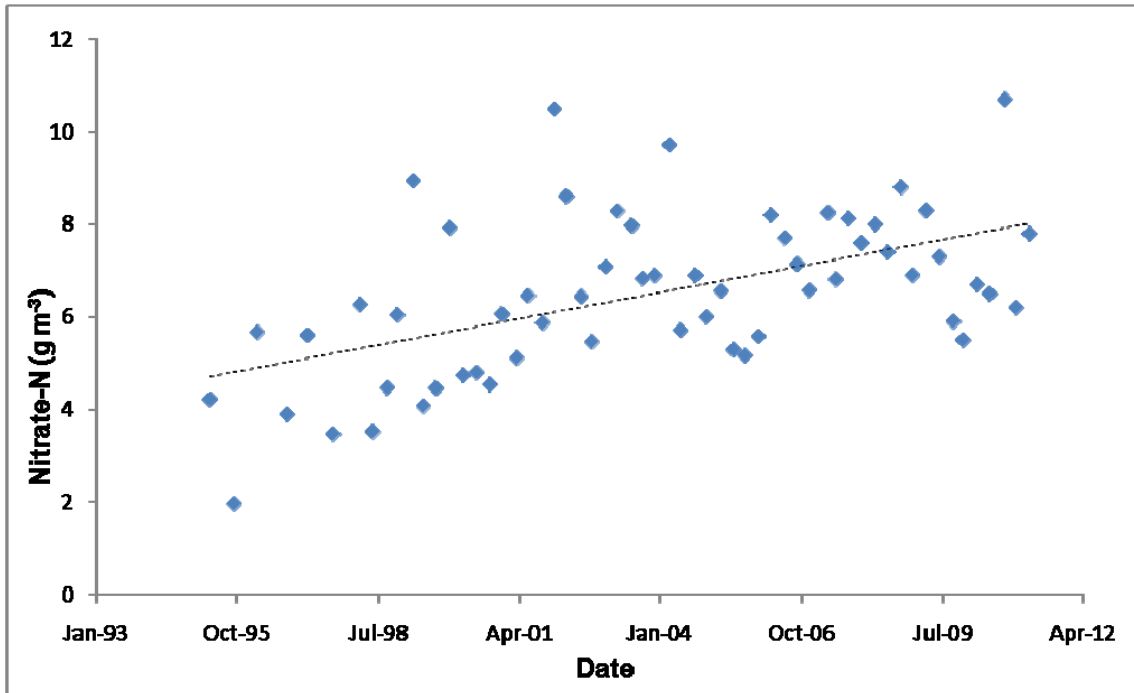


Figure 6: Nitrate concentration trend in well 61_126

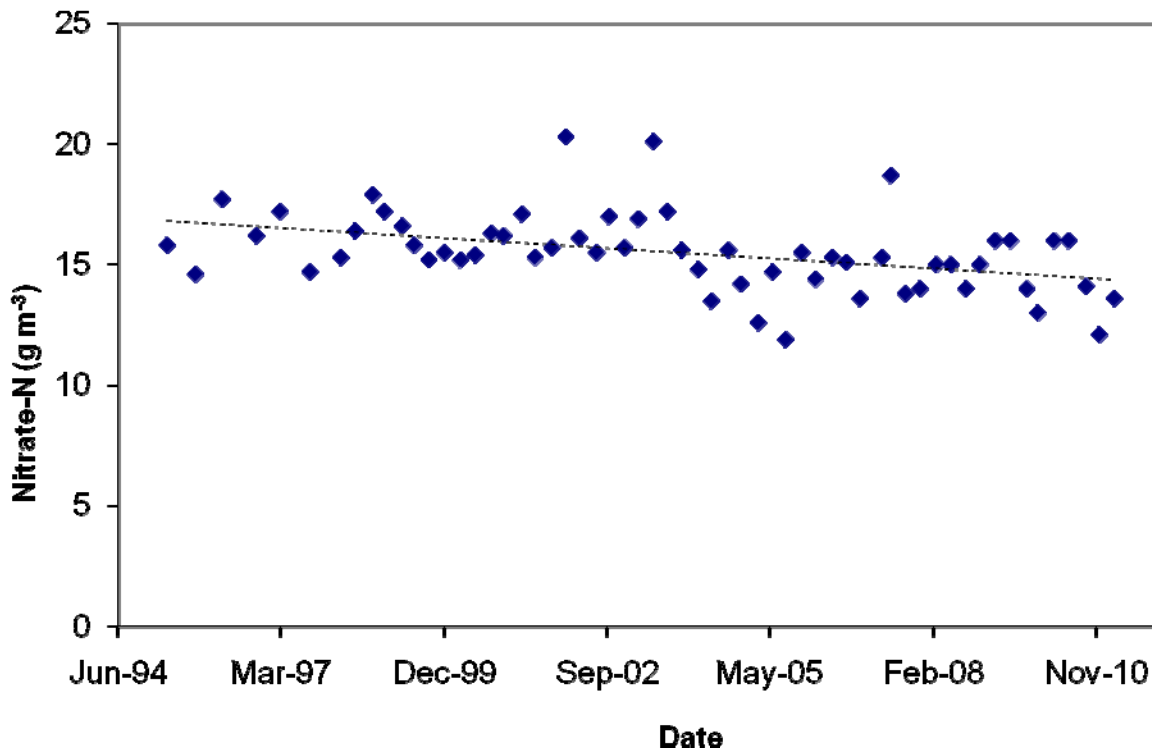


Figure 7: Nitrate concentration trend in well 61_208

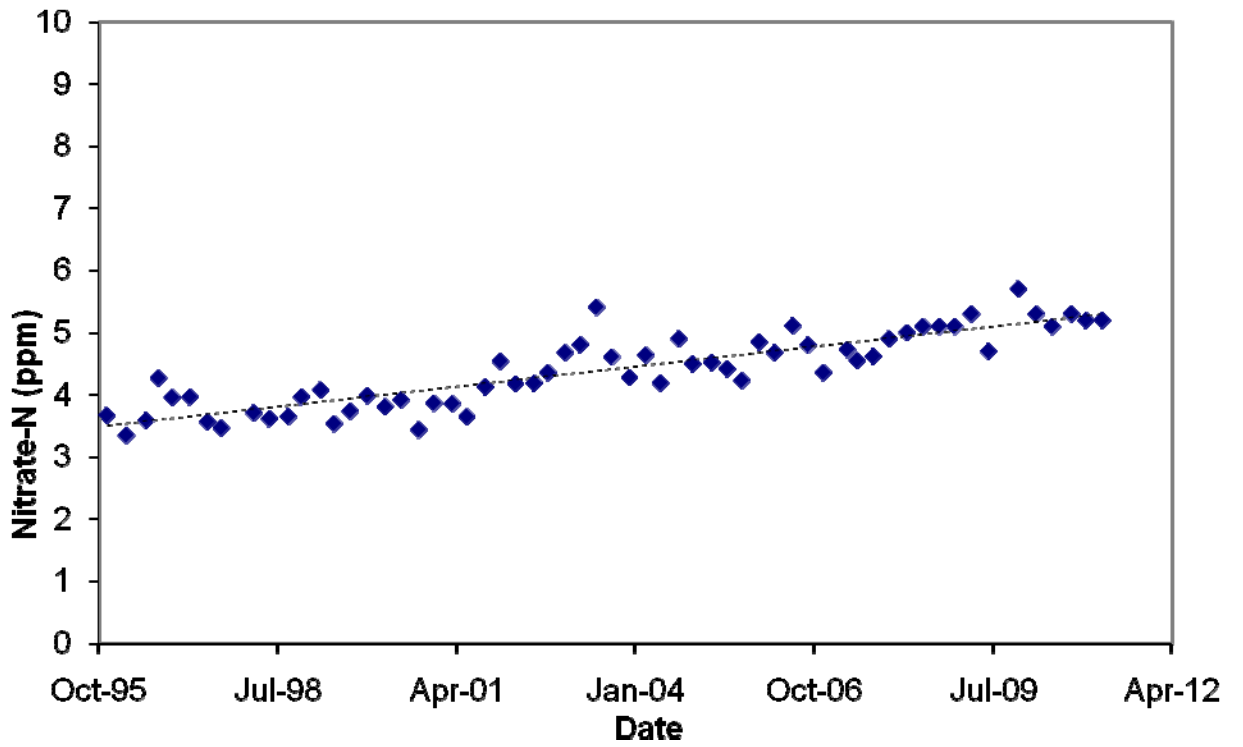


Figure 8: Nitrate concentration trend in well 61_221

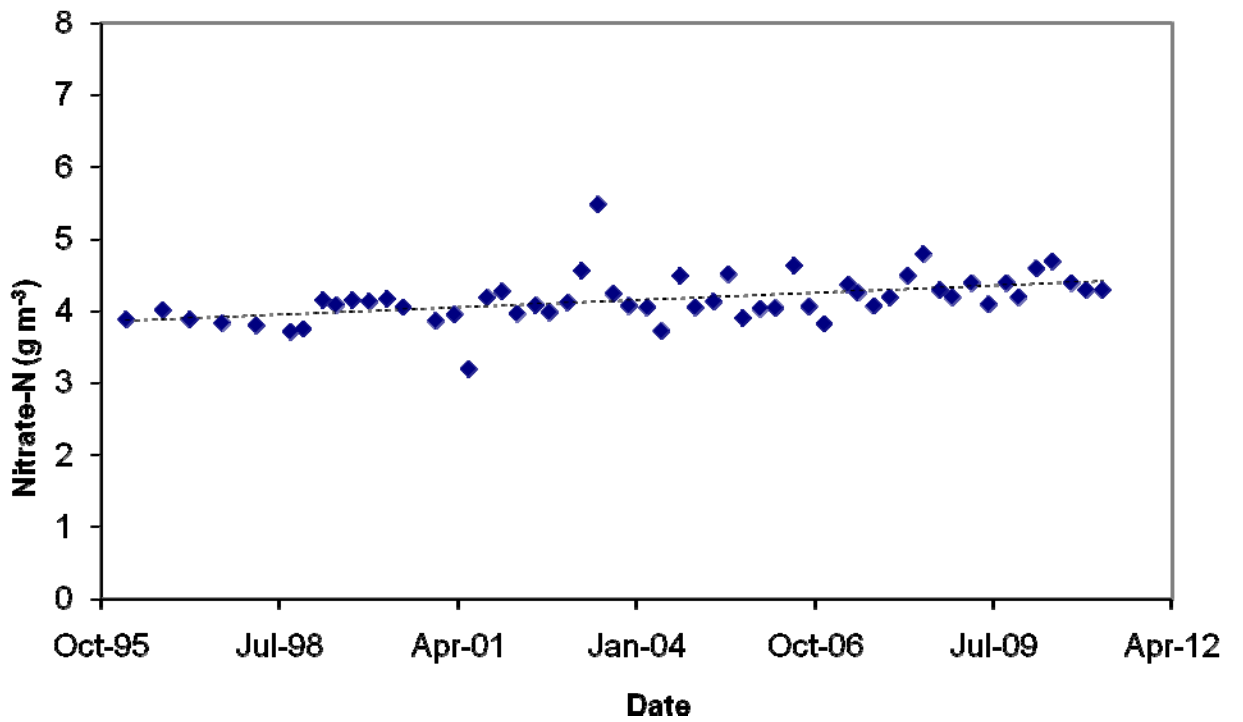


Figure 9: Nitrate concentration trend in well 61_59

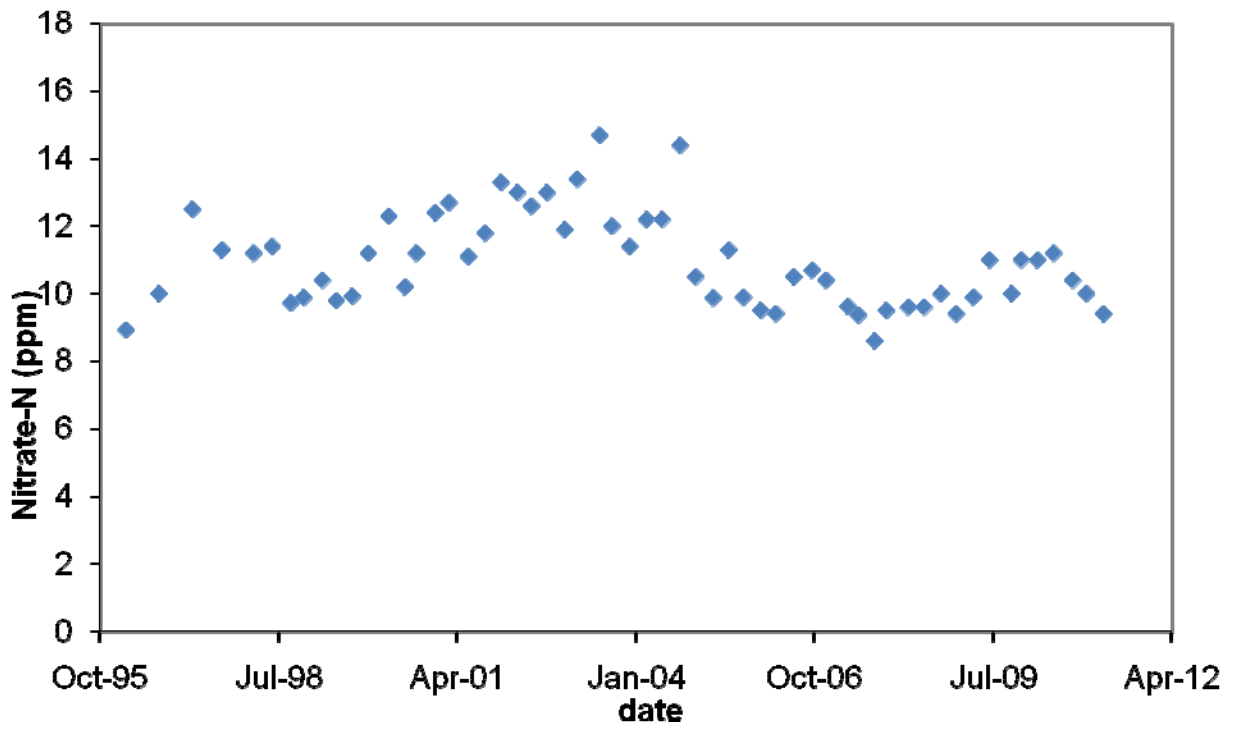


Figure 10: Nitrate concentration trend in well 63_57

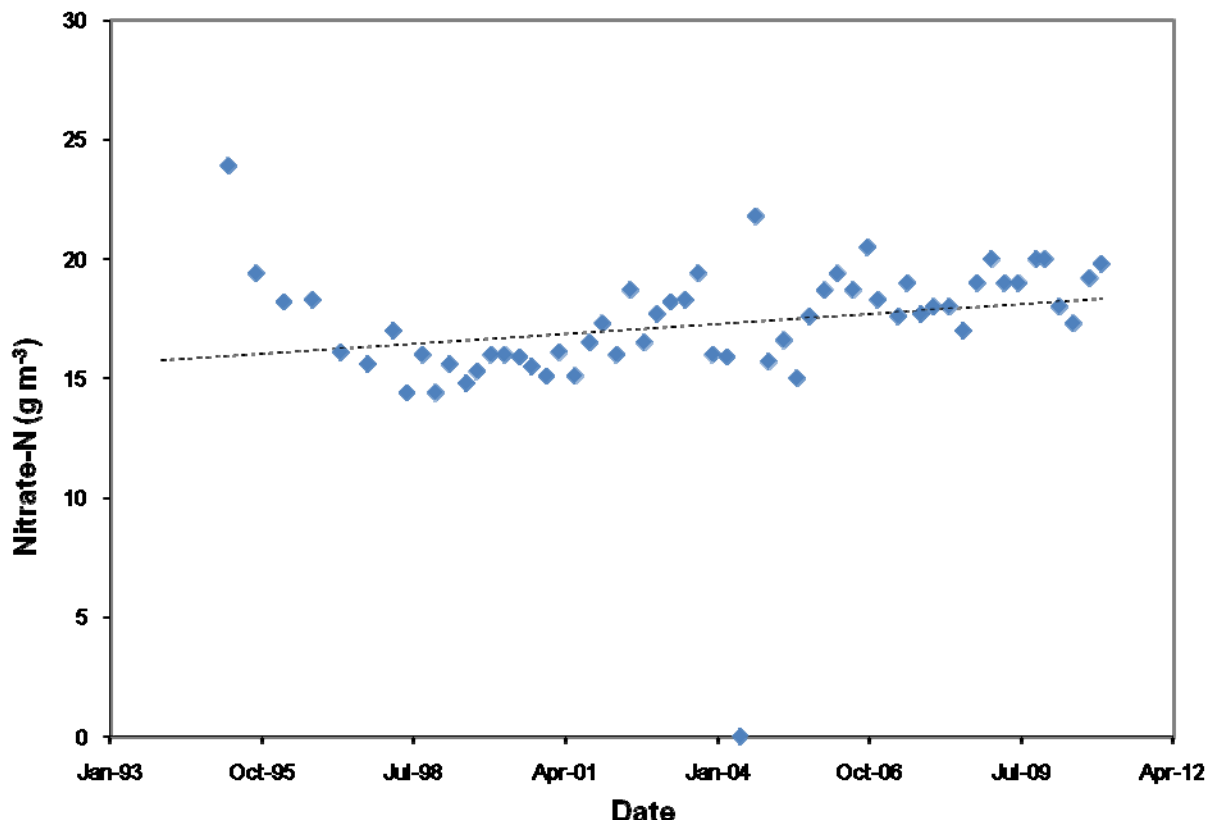


Figure 11: Nitrate concentration trend in well 64_108

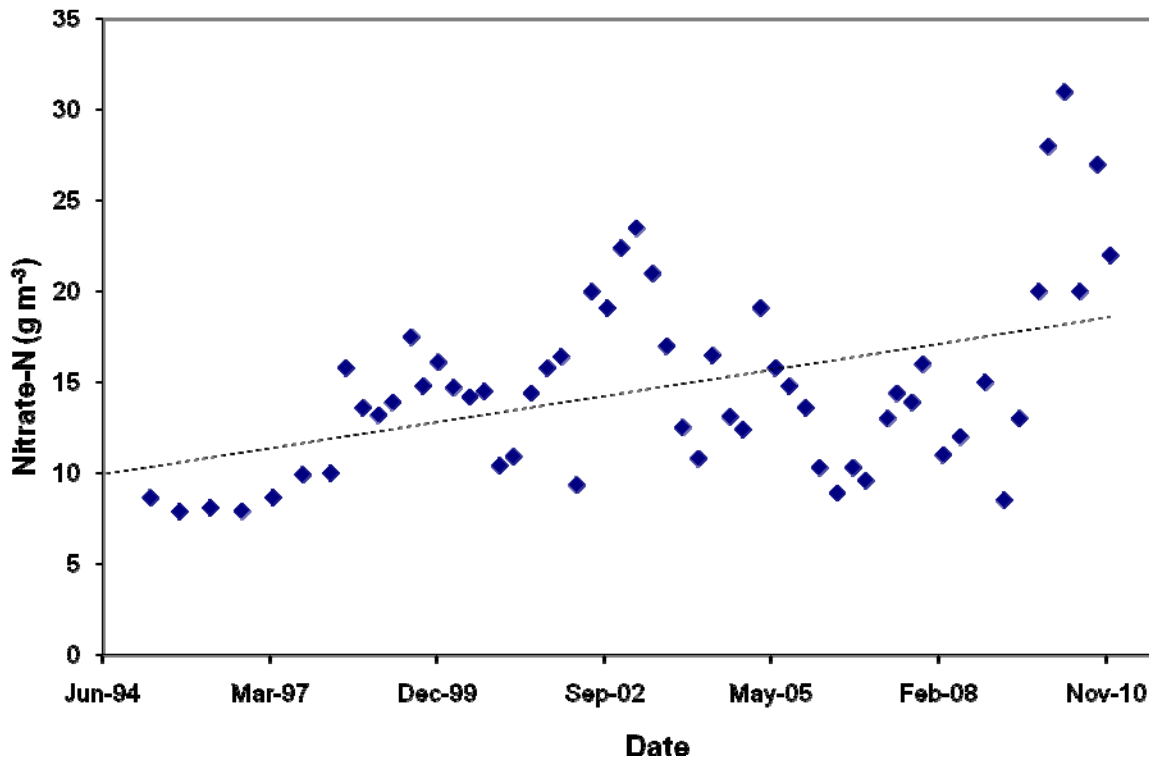


Figure 12: Nitrate concentration trend in well 64_117

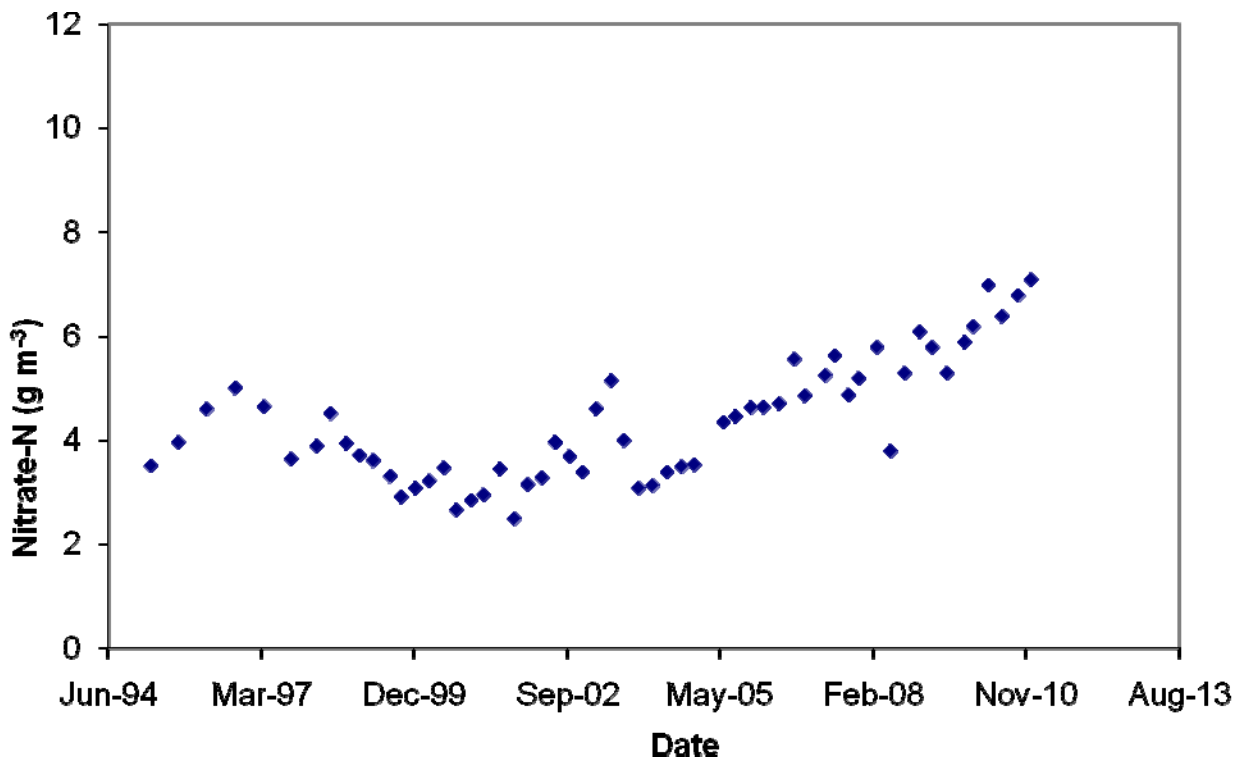


Figure 13: Nitrate concentration trend in well 64_12

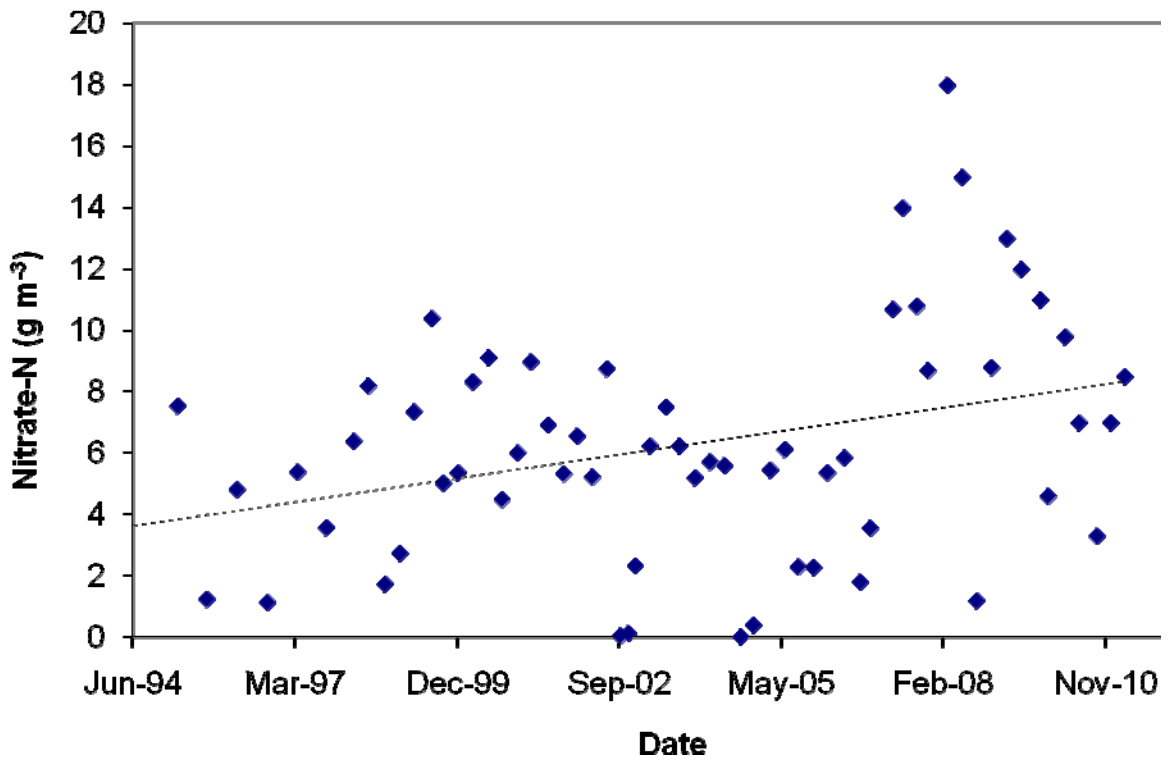


Figure 14: Nitrate concentration trend in well 64_20

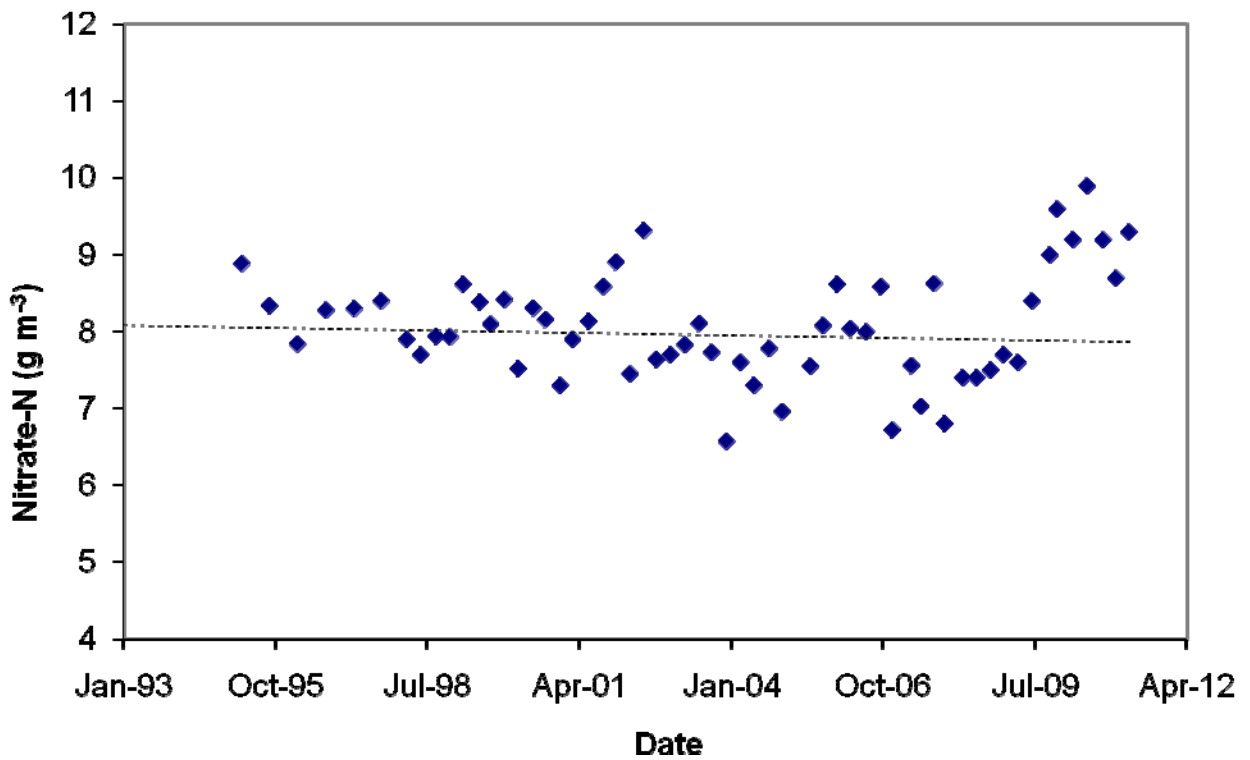


Figure 15: Nitrate concentration trend in well 64_43

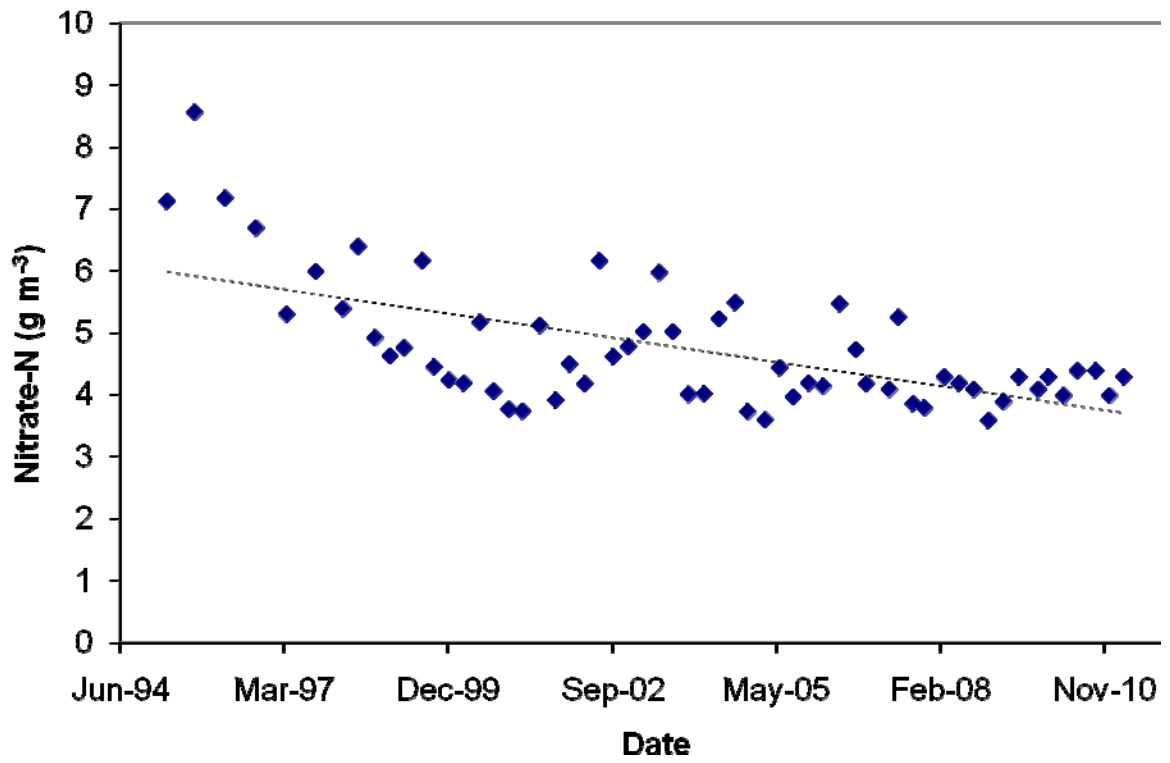


Figure 16: Nitrate concentration trend in well 64_46

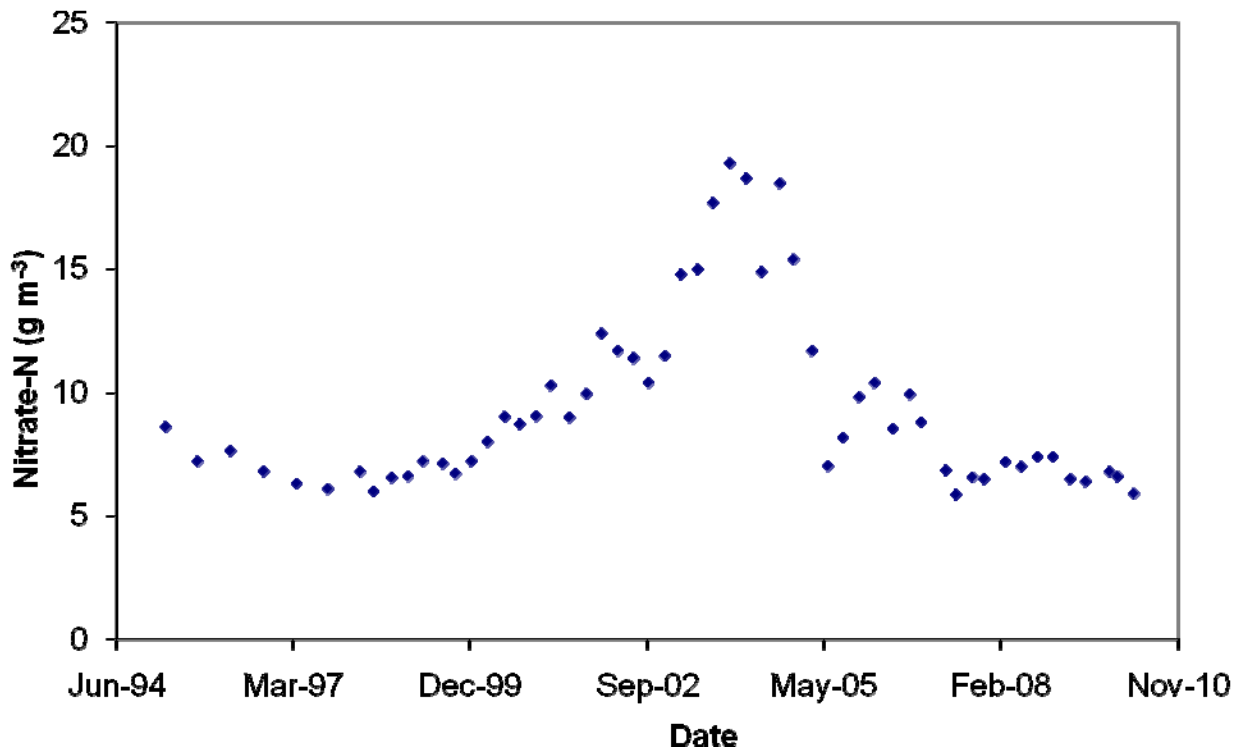


Figure 17: Nitrate concentration trend in well 64_50

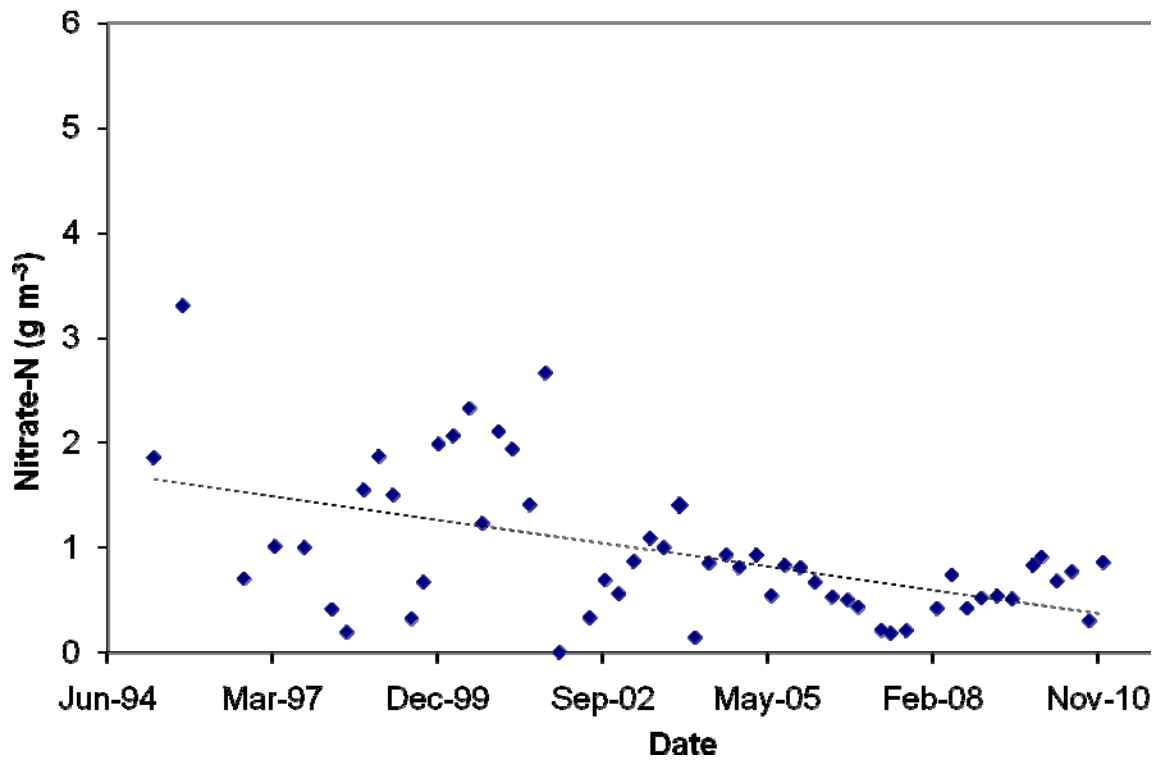


Figure 18: Nitrate concentration trend in well 64_70

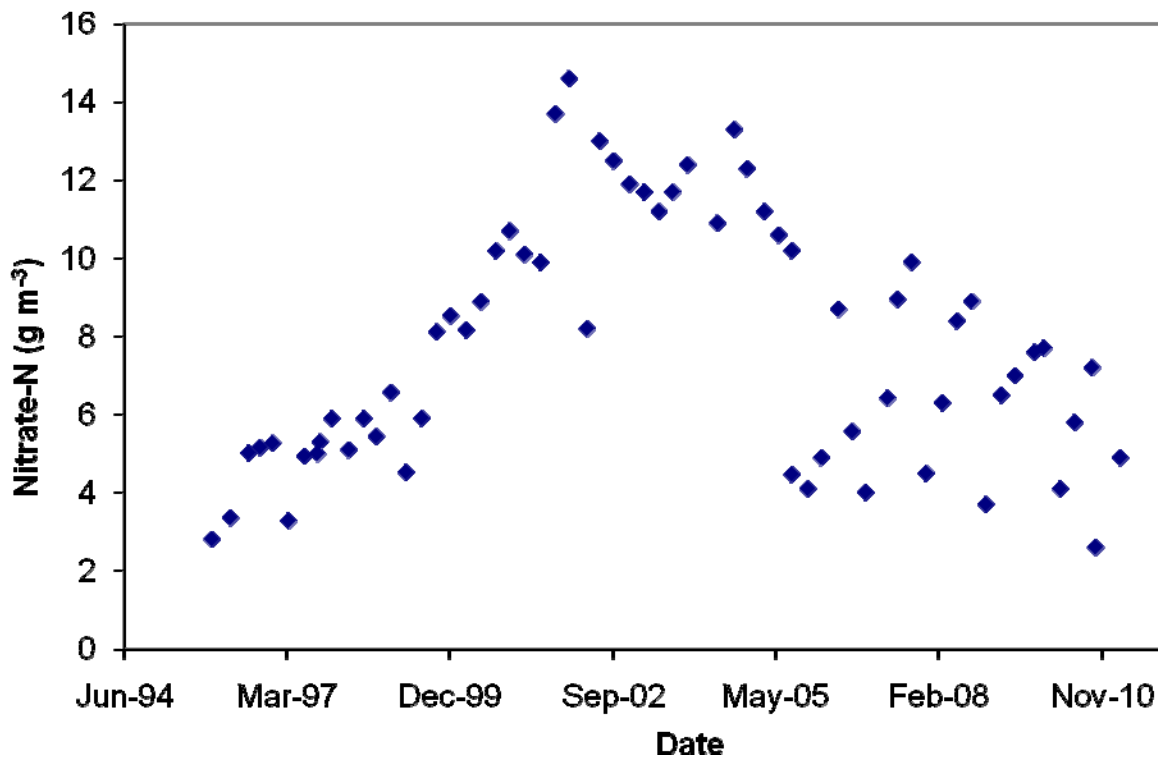


Figure 19: Nitrate concentration trend in well 64_120

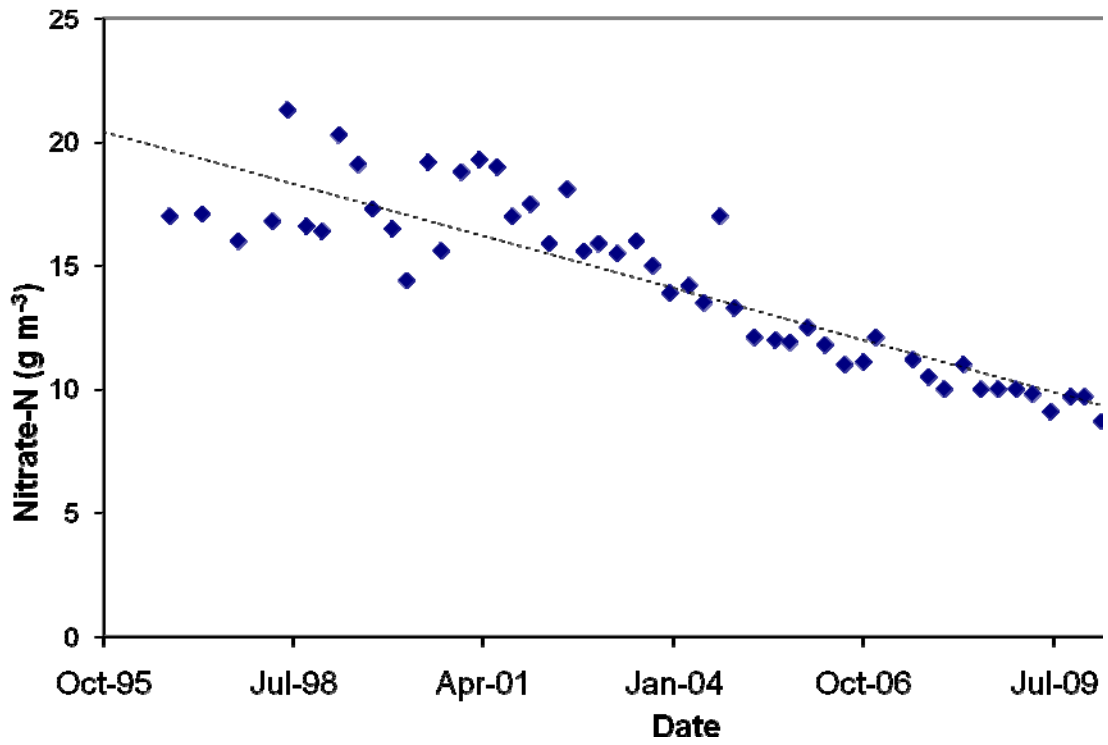


Figure 20: Nitrate concentration trend in well 66_6

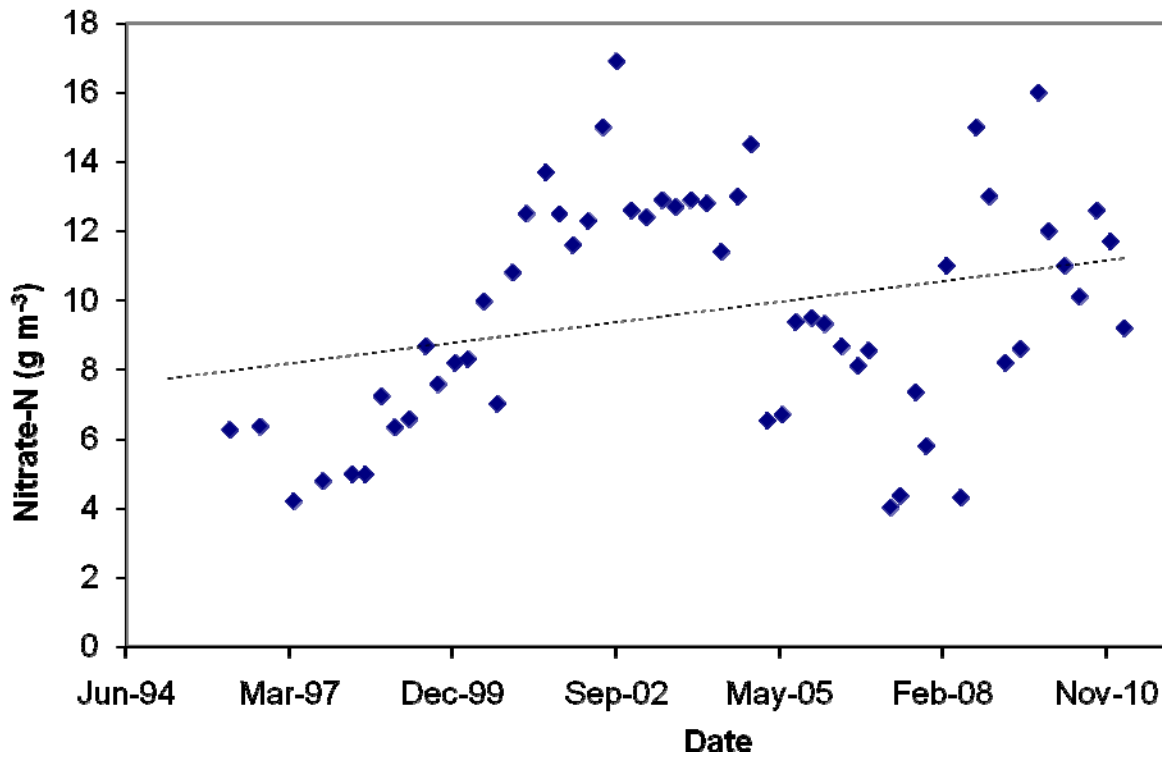


Figure 21: Nitrate concentration trend in well 67_11

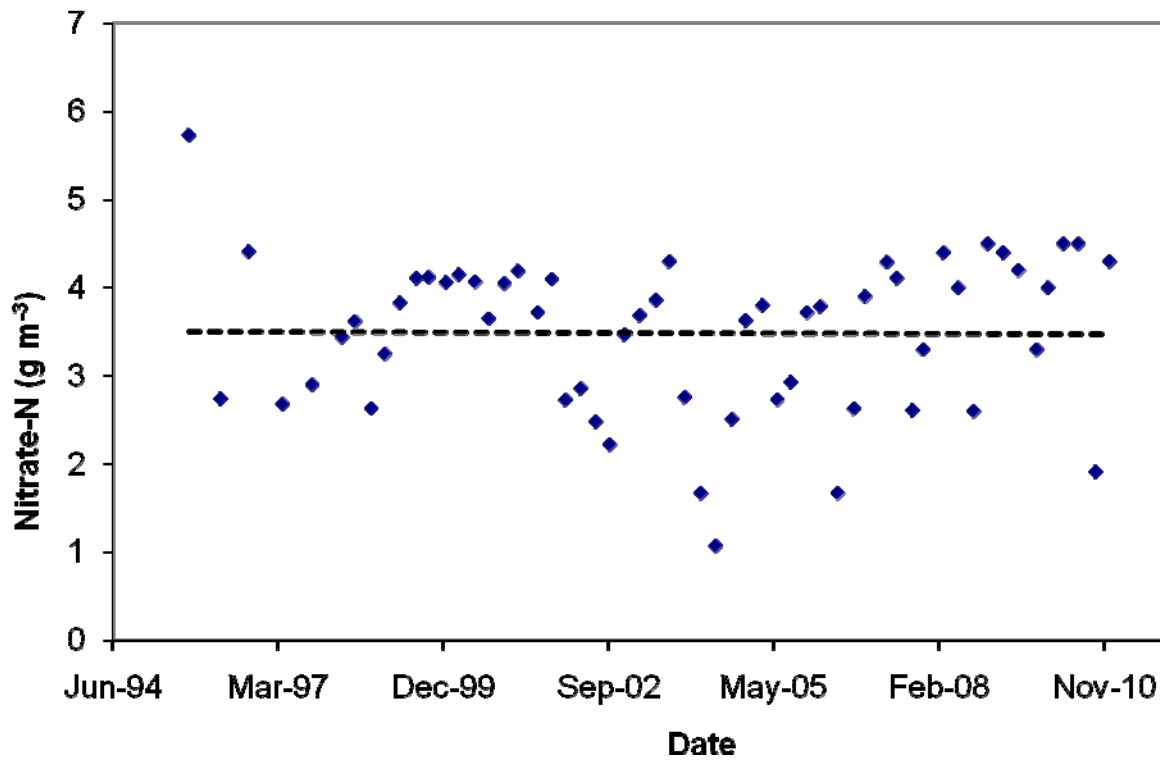


Figure 22: Nitrate concentration trend in well 67_15

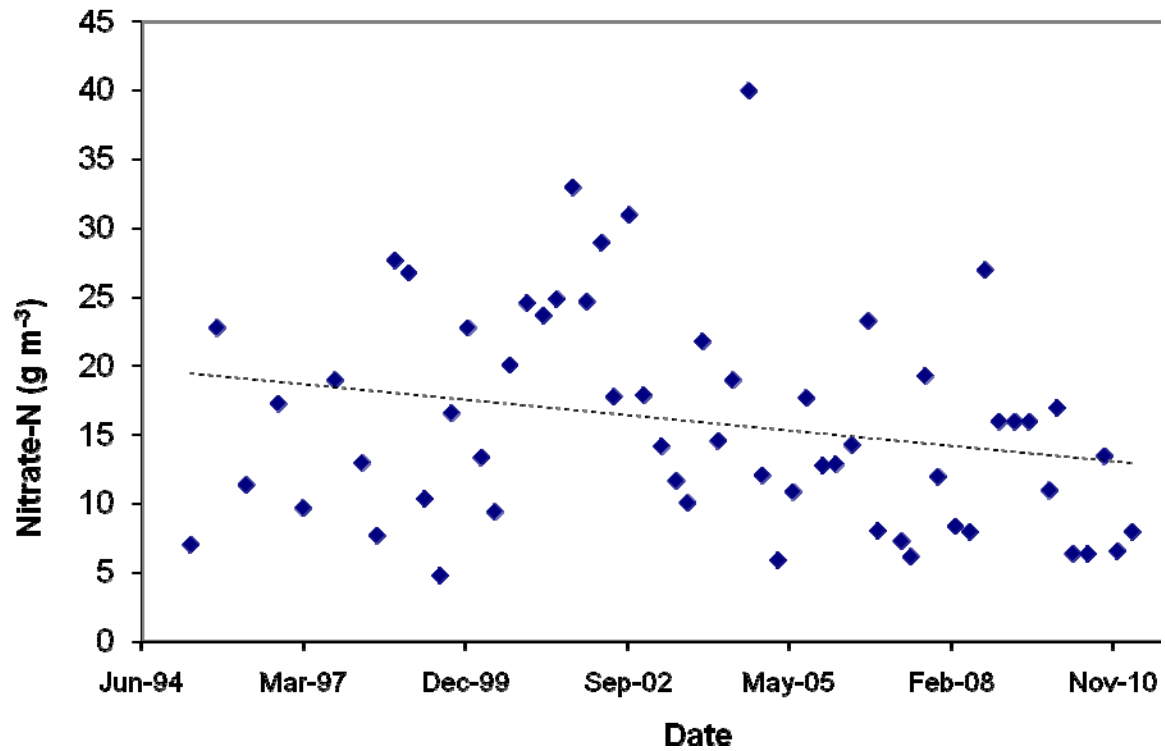


Figure 23: Nitrate concentration trend in well 69_173

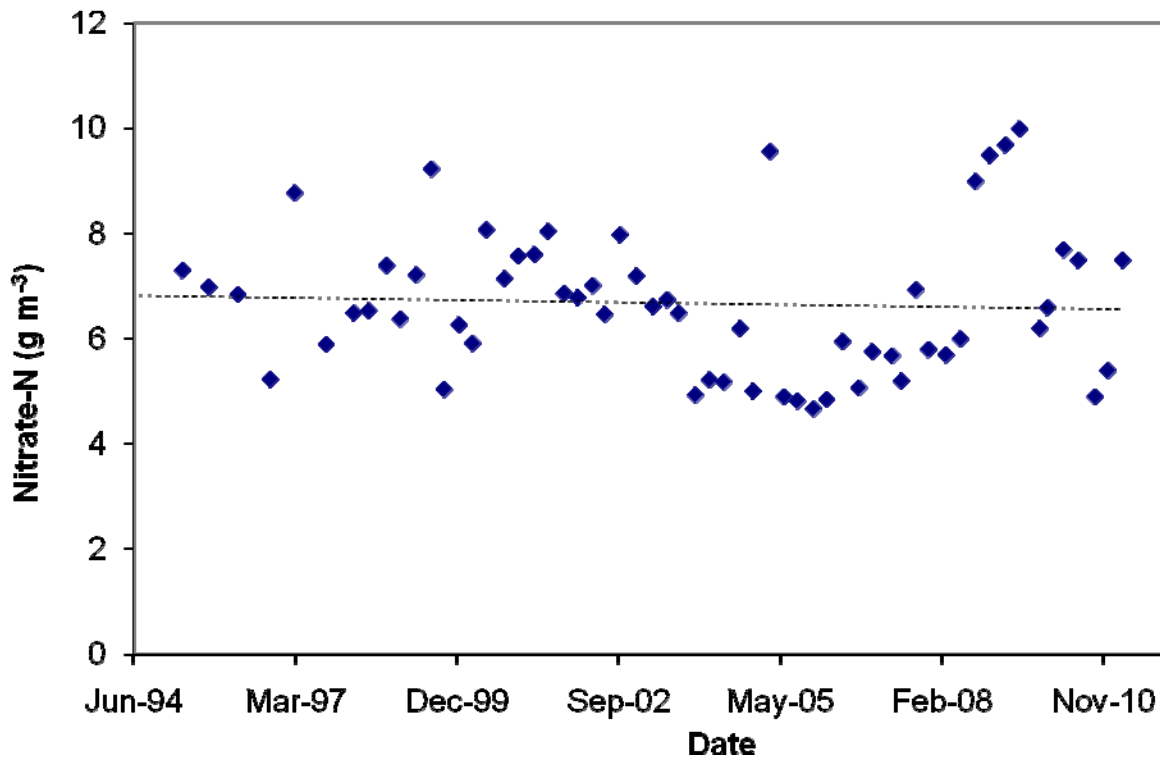


Figure 24: Nitrate concentration trend in well 69_365

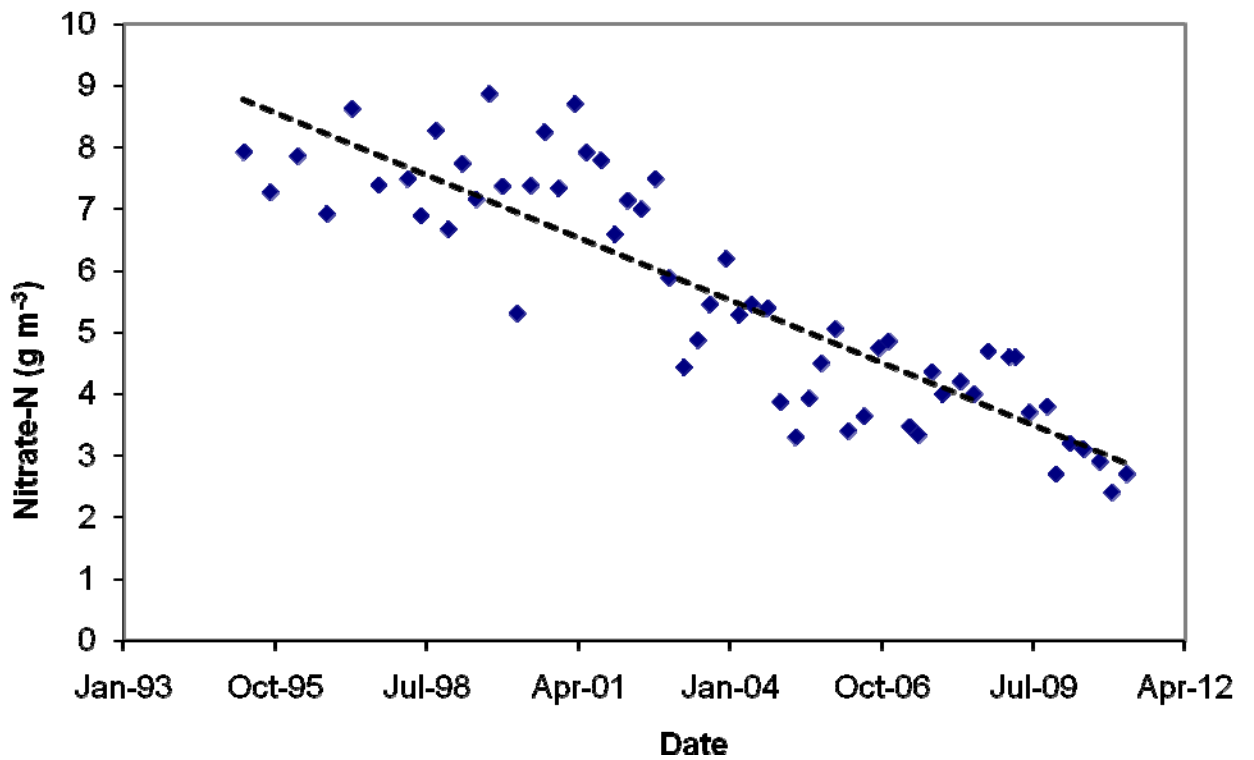


Figure 25: Nitrate concentration trend in well 69_81

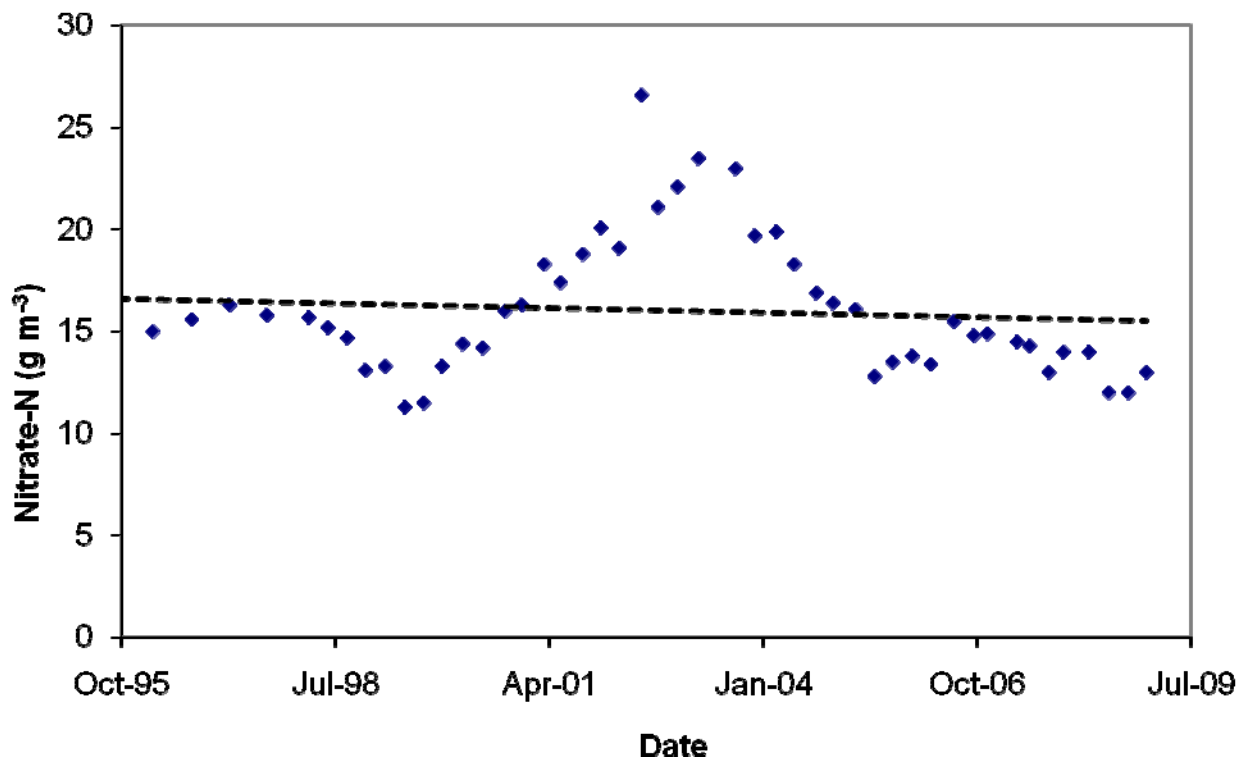


Figure 26: Nitrate concentration trend in well 70_44

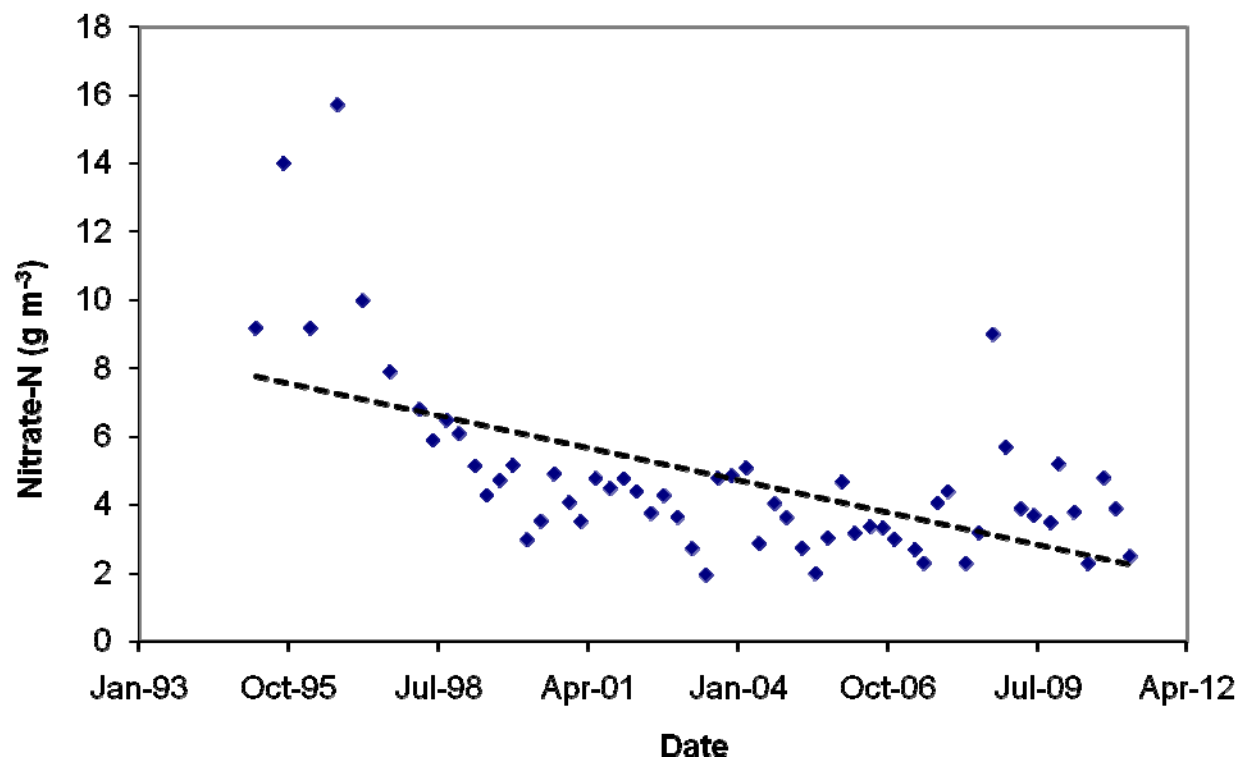


Figure 27: Nitrate concentration trend in well 70_47

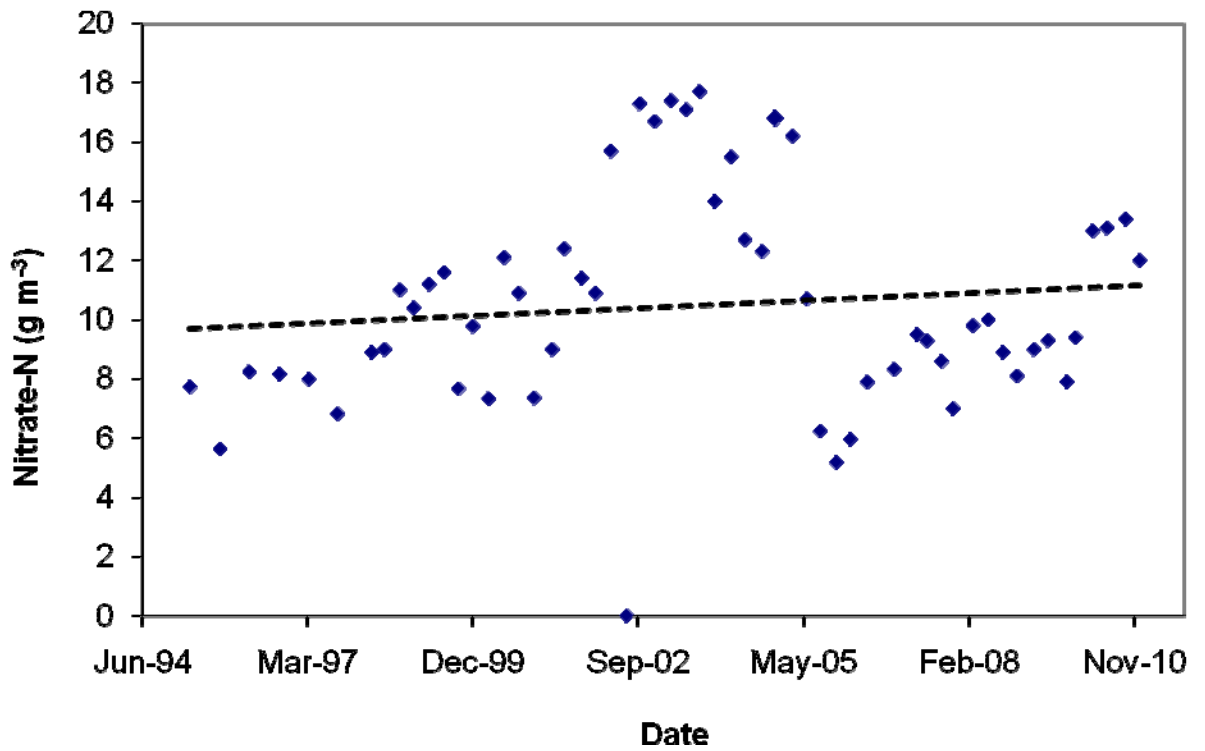


Figure 28: Nitrate concentration trend in well 70_56

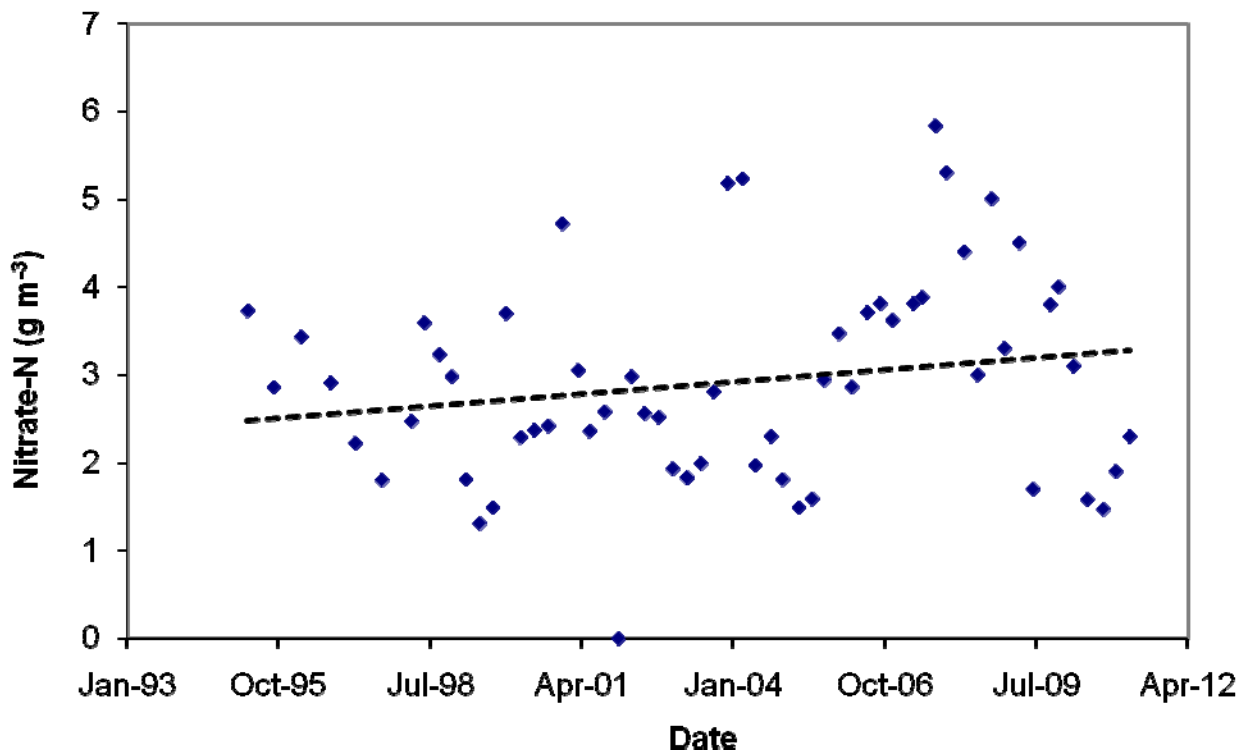


Figure 29: Nitrate concentration trend in well 70_65

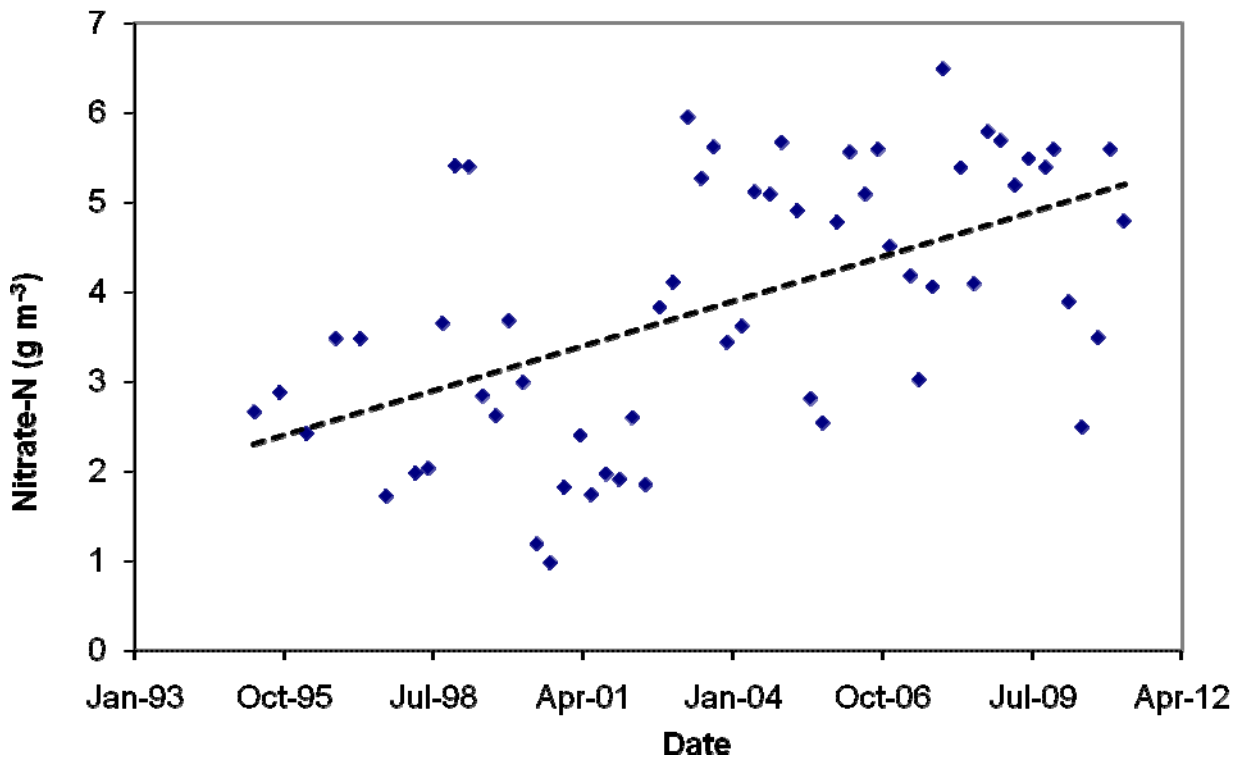


Figure 30: Nitrate concentration trend in well 70_74

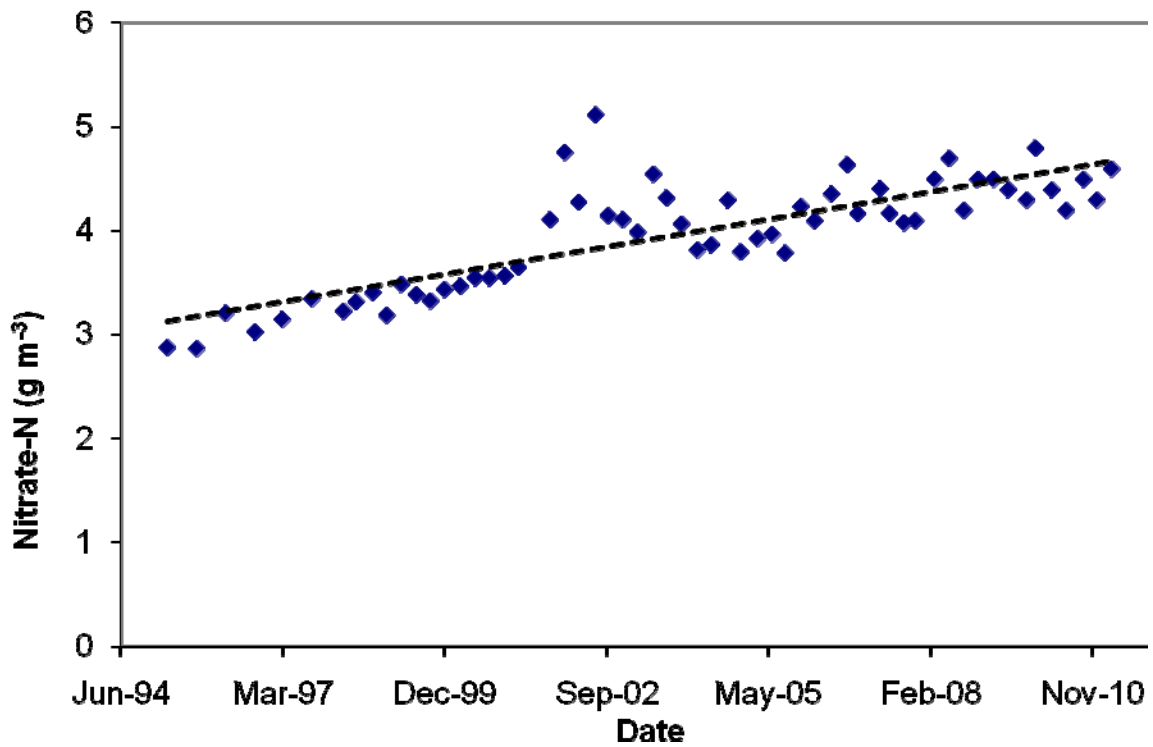


Figure 31: Nitrate concentration trend in well 70_76

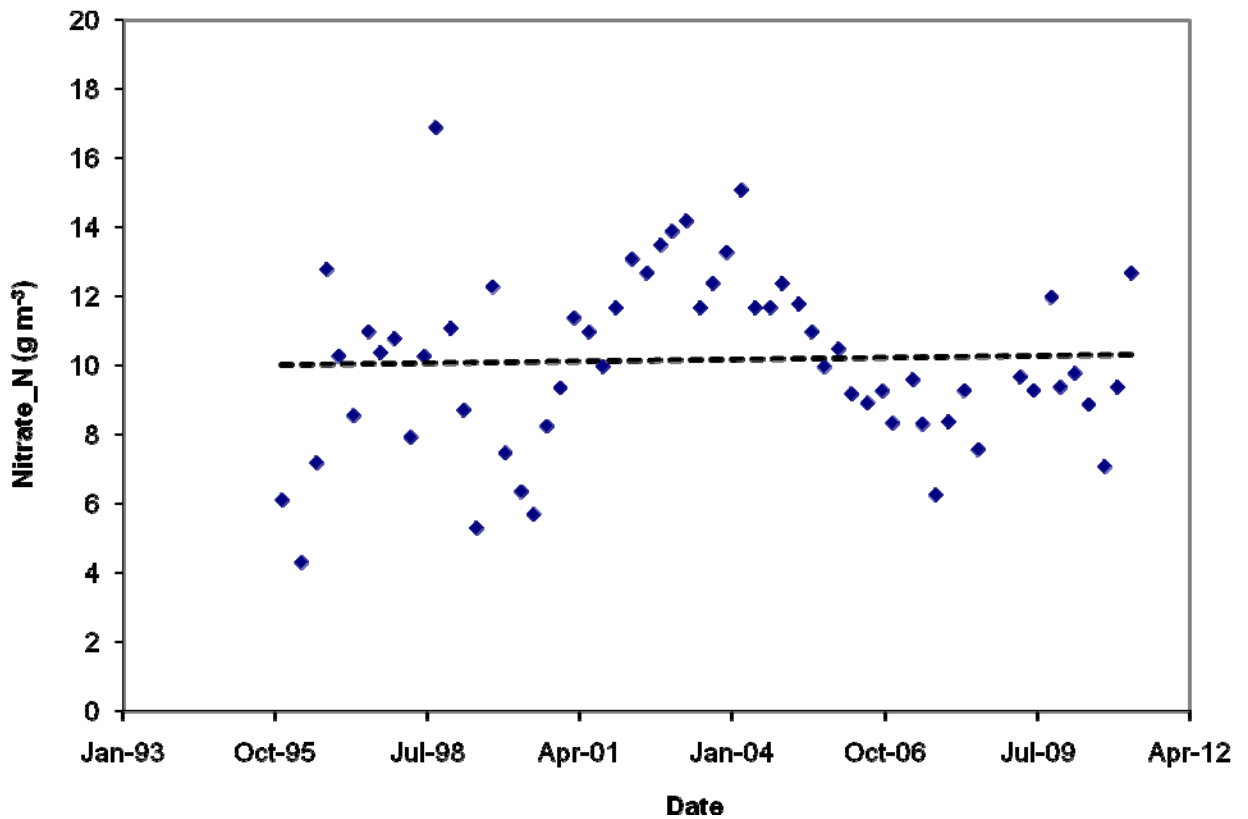


Figure 32: Nitrate concentration trend in well 70_21

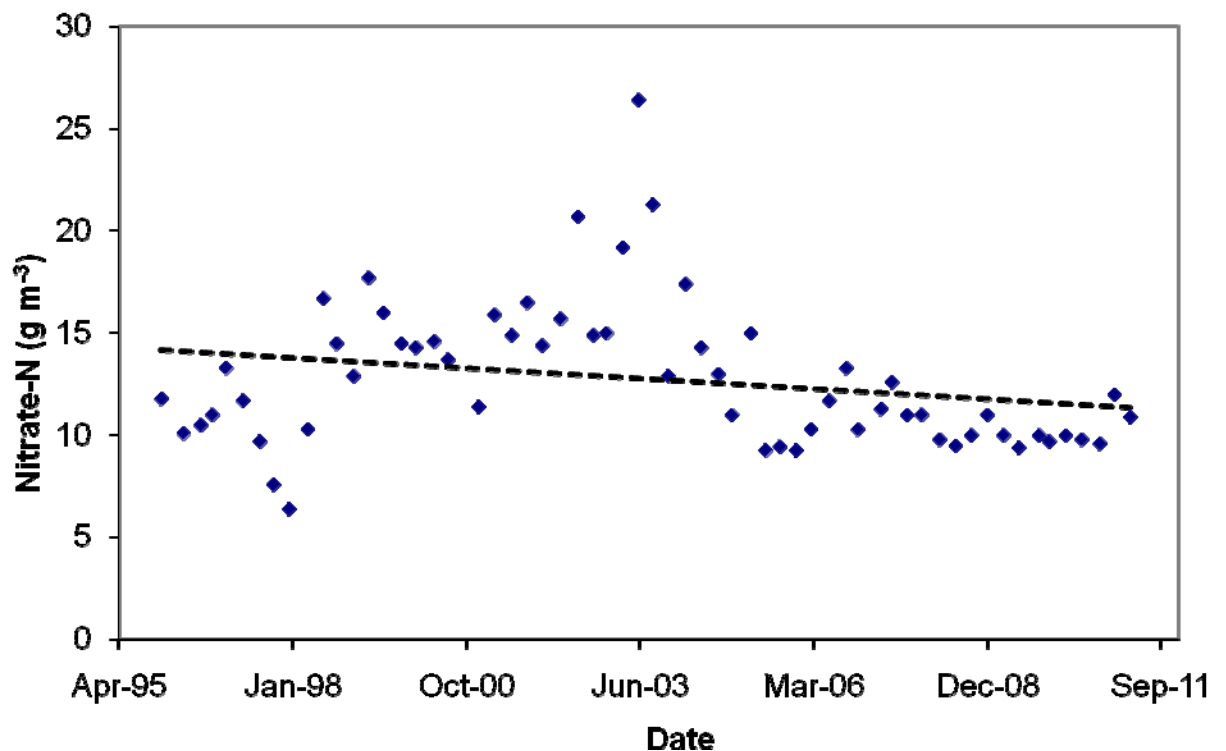


Figure 33: Nitrate concentration trend in well 70_22

3.6 Pesticide trends

The occurrence of pesticides in groundwater is a concern for human health and may have implications for other uses such as stock watering and crop irrigation (s3.9 WRP). Poor management and use of agrichemicals may result in contamination of water supplies by hazardous substances. These may cause a range of both acute and or chronic health effects.

An investigation into pesticide contamination of groundwater in high use areas of the Waikato was undertaken in 1995 (Hadfield and Smith, 2000). Aquifers considered to be particularly vulnerable to contamination were targeted by sampling groundwater at 35 sites in the Pukekohe/Pukekawa and Hamilton Basin/southern Hauraki Plains areas. Detectable pesticide residues were found at 74% of the wells sampled. A total of 20 different, mostly persistent and mobile, pesticide active ingredients were identified. Atrazine, alachlor, diuron, simazine, terbuthylazine and procymidone were most commonly detected.

The concentrations of pesticides detected were generally well below the maximum acceptable values (MAV) for drinking water. Notable exceptions were two sites where dieldrin (from nearby former sheep-dips) was detected above MAV. Subsequent quarterly monitoring of 20 of the sites, undertaken over three years, indicated considerable temporal variation in pesticide concentration and occurrence. A close relationship between pesticides detected in groundwater and those used at the site was apparent in five cases in the Hamilton Basin. The majority of pesticides in use, however, were not detected. Direct entry of pesticides into wells (e.g. during mixing) was indicated at some sites from relatively high concentrations and rapid response. There were also instances where detected pesticides were the result of historic use. Pesticides detected at several sites (at least five) apparently relate to chemical use at a neighbouring property. Much of the pesticide contamination detected is a legacy of past use or poor management practices. Careful chemical selection and management is needed to avoid adverse effects.

Quarterly sampling at four wells has been retained and temporal variation in pesticide occurrence is illustrated below. All of these wells abstract from shallow, unconfined aquifers and located on properties with common pesticide use. These show the detection of 15 pesticides at both wells 61.113 and 70_22 and 12 at well 64_120. All of these wells show declines in pesticide occurrence. The exception is well 70_21 where 10 pesticides have been detected but these occurrences have increased since 2004. Recent spray diary information can be used to analyse the migration and fate of pesticides used. The concentrations detected are well below drinking water standard MAVs.

As well as the quarterly monitoring illustrated a total of 80 wells, comprising 40 each from the regional and community networks, are monitored every four years and reported as an indicator on the Waikato Regional Council website www.waikatoregion.govt.nz.

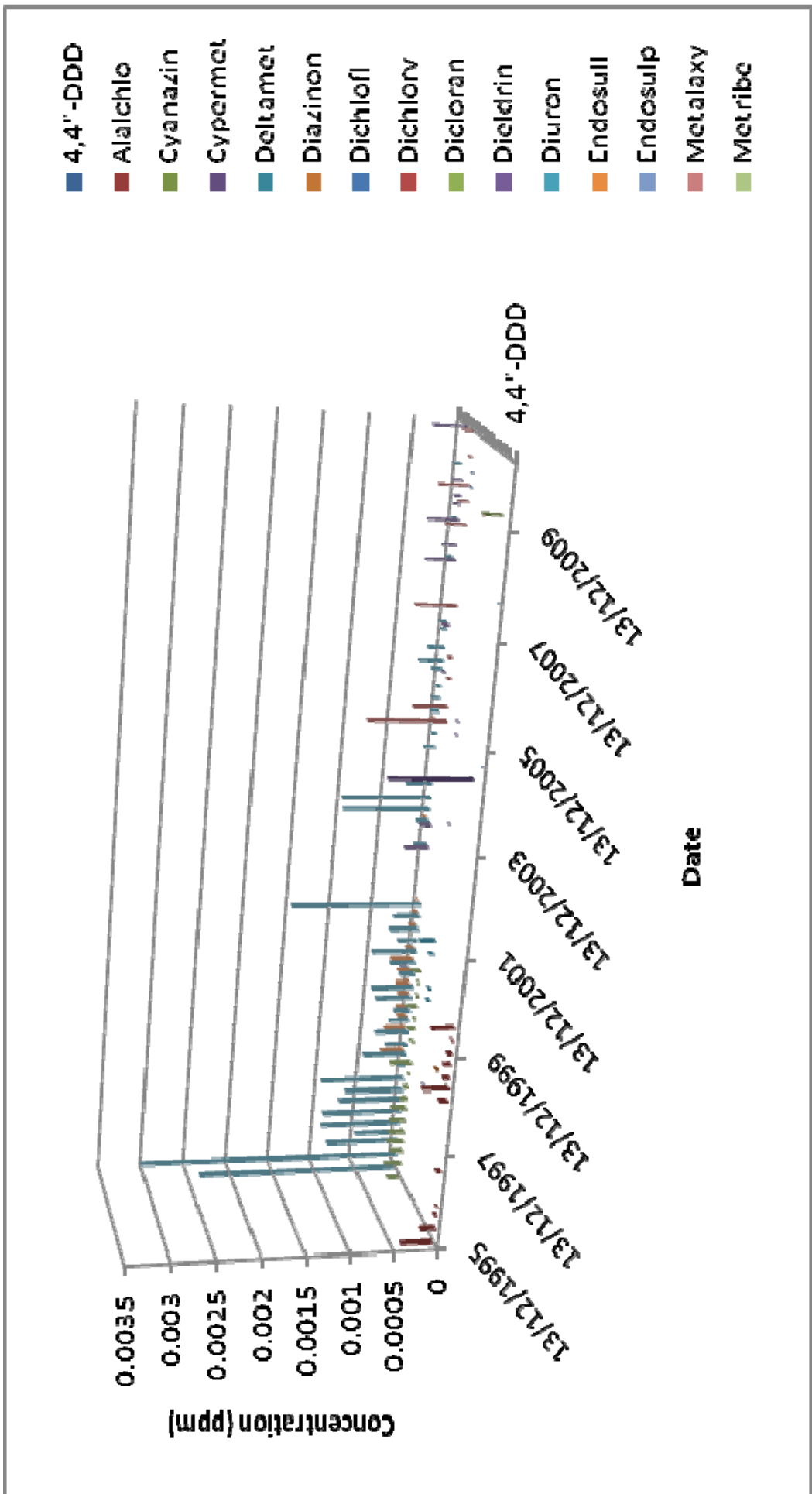


Figure 34: Pesticide occurrence at well 61_113

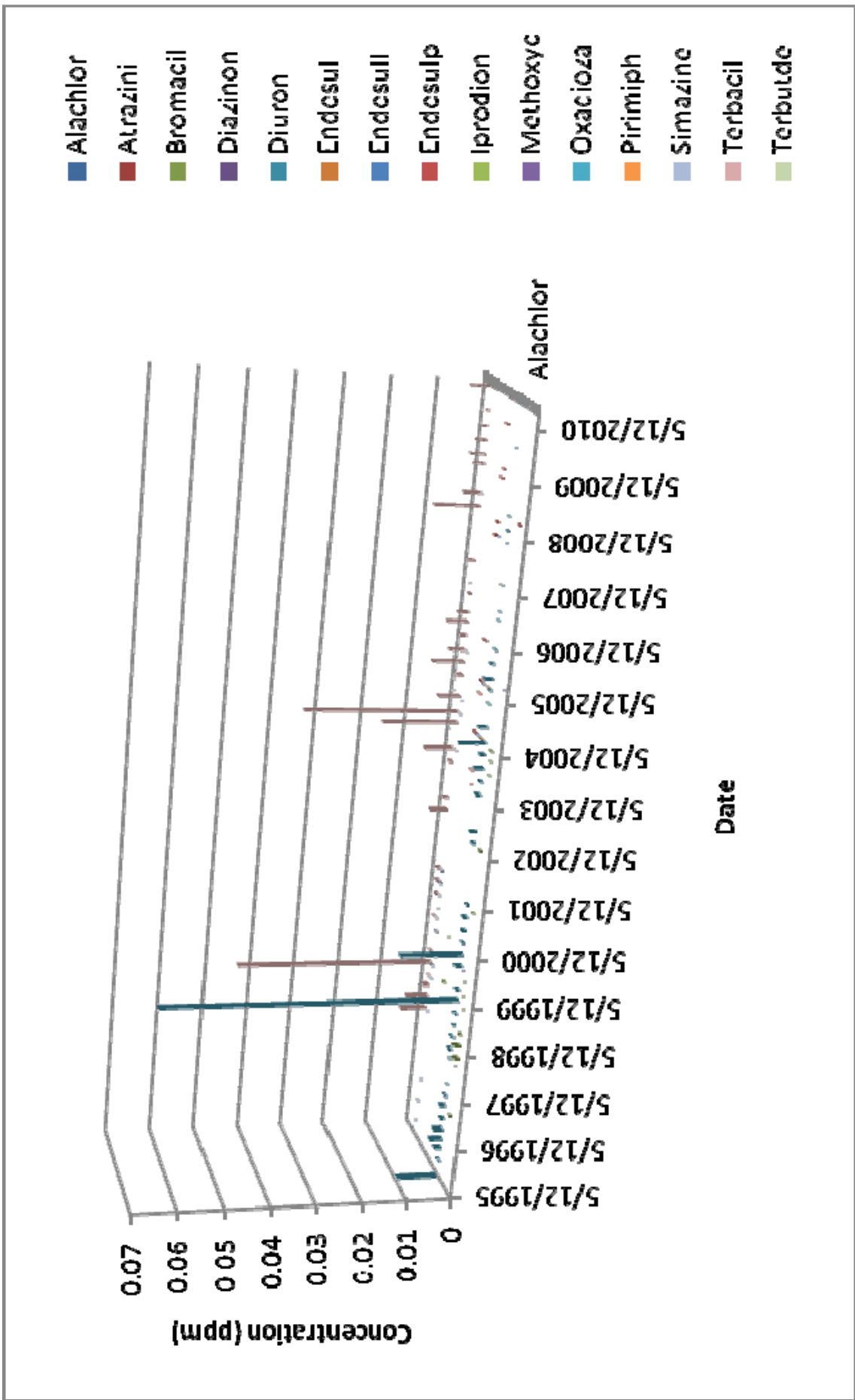


Figure 35: Pesticide occurrence at well 70_22

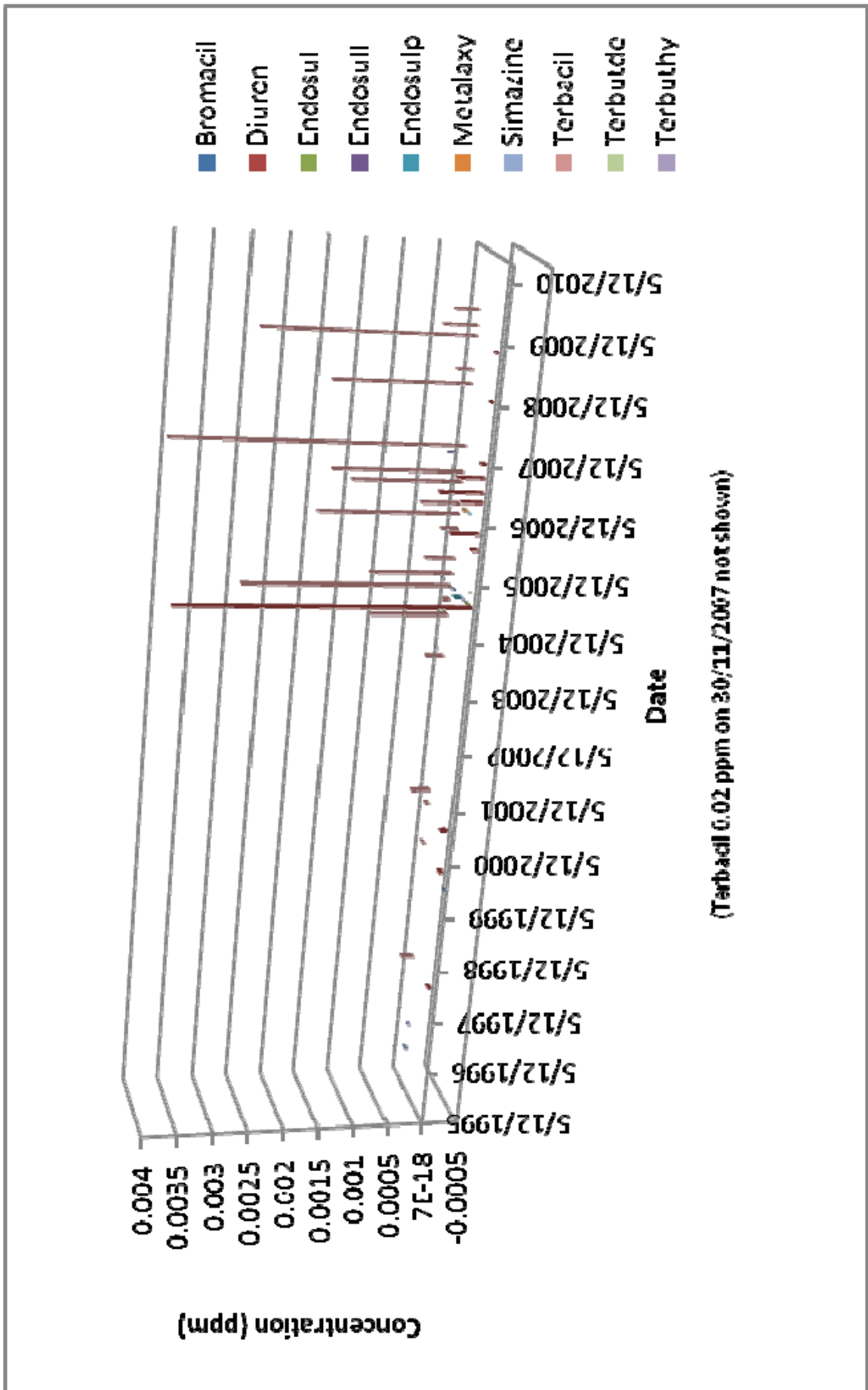


Figure 36: Pesticide occurrence at well 70_21

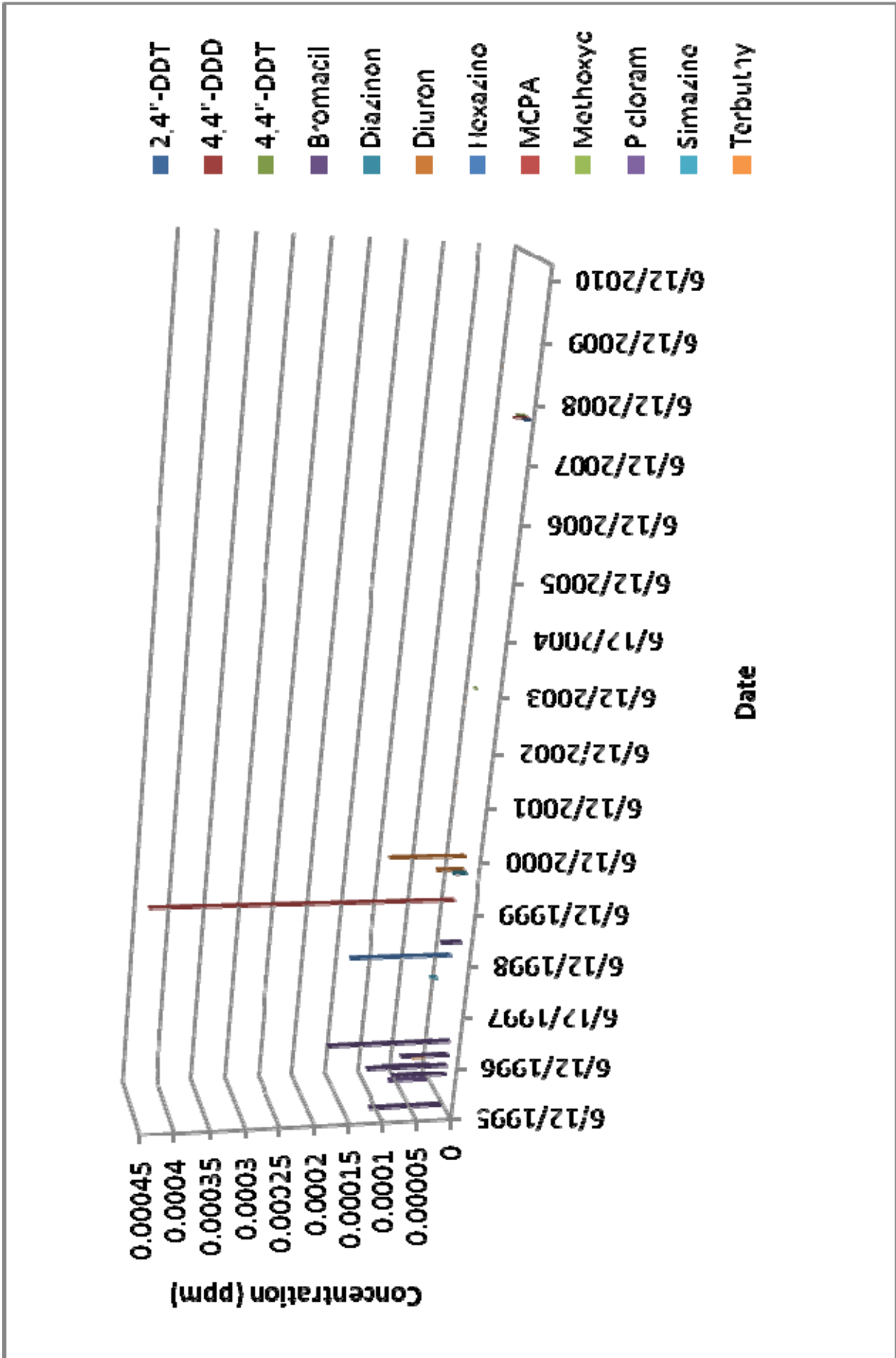


Figure 37: Pesticide occurrence at well 64_120 (from doc 1971960)

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Appendix I: Regional groundwater quality network sampling records and frequency

(grey shading signifies quarterly sampling and grey hashed is annual sampling).

Well	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Coromandel																
60-12	[Quarterly Sampling]															
60-124	[Quarterly]	[Quarterly]	[Quarterly Sampling]													
60-167	[Annual Sampling]															
60-190	[Quarterly Sampling]															
60-316	[Quarterly Sampling]															
60-345	[Quarterly Sampling]															
60-348	[Quarterly]	[Quarterly]	[Quarterly Sampling]													
60-4	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
72-3559	[Annual Sampling]															
60-407	[Quarterly Sampling]															
60-480	[Quarterly Sampling]															
60-483	[Annual Sampling]															
72-2691	[Annual Sampling]															
Franklin																
61-113	[Quarterly Sampling]															
61-126	[Quarterly Sampling]															
61-135	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-143	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-208	[Quarterly Sampling]															
61-221	[Quarterly Sampling]															
61-230	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-245	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-258	[Quarterly Sampling]															
61-280	[Quarterly Sampling]															
61-54	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-59	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-702	[Quarterly Sampling]															
61-85	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
61-93	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
Hauraki																
63-201	[Quarterly Sampling]															
63-240	[Quarterly Sampling]															
63-328	[Quarterly Sampling]															
63-43	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
63-57	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
63-74	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
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72-1223	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
Matamata-Piako																
64-108	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
64-111	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
64-117	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]
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64-120	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]	[Quarterly]

64-20		
64-43		
64-46		
64-50		
64-511		
64-7		
64-70		
64-720		
64-831		
Otorohonga		
65-4		
65-6		
65-8		
Rotorua		
66-58		
66-6		
66-92		
66-93		
66-96		
South Waikato		
67-11		
67-15		
72-4500		
67-4		
67-404		
67-435		
67-483		
67-55		
67-573		
67-83		
Taupo		
68-301		
68-317		
68-320		
68-661		
68-912		
68-964		
72-1008		
72-1011		
72-1069		
72-1072		
72-1081		
72-1082		
72-1087		
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Waikato		
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69-97 [redacted]
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Waipa

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70-47 [redacted]
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70-76 [redacted]

Waitomo

71-1 [redacted]
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71-3 [redacted]
71-4 [redacted]
71-5 [redacted]

Appendix II: Groundwater quality analysis methods and detection limits

Determinand	Units	Detection limit	Method description
ALKT	g/m ³ -CaCO ₃	1	Potentiometric autotitration to pH 4.5. APHA 2320B.
As	g/m ³	0.0011	ICP-MS after HNO ₃ digestion. APHA 3125 B.
B	g/m ³	0.0053	ICP- MS after HNO ₃ digestion. APHA 3125B.
Ca	g/m ³	0.053	ICP-MS after HNO ₃ digestion. APHA 3215 B.
Cd (D)	g/m ³	0.00005	Filtered, ICP-MS APHA 3125B
Cd T	g/m ³	0.053	ICP-MS after HNO ₃ digestion. APHA 3125B.
Cl	g/m ³	0.5	Filtered sample, Ion chromatography. APHA 4110B.
Cond	mS/m @25°C	0.1	Measured in lab by meter @ 25°C. APHA Method 2510B
Cu	g/m ³	0.00053	ICP-MS after HNO ₃ digestion. APHA 3125B.
F	g/m ³	0.021	Specific ion electrode.APHA 4500-FC.
Fe (D)	g/m ³	0.02	Filtered, ICP-MS APHA 3125B
Fe	g/m ³	0.021	ICP-MS after HNO ₃ digestion. APHA 3125B.
Free CO ₂	g/m ³ -CO ₂	1	Free Carbon Dioxide Calculation from alkalinity & pH (APHA 4500 CO ₂ D)
Hardness	g/m ³ -CaCO ₃	1	Calculation from Ca and Mg. APHA 2340B.
K	g/m ³	0.053	ICP-MS after HNO ₃ digestion. APHA 3215 B.
Mg	g/m ³	0.021	ICP-MS after HNO ₃ digestion. APHA 3215 B.
Mn (D)	g/m ³	0.0005	Filtered, ICP-MS APHA 3125B
Mn	g/m ³	0.00053	ICP-MS after HNO ₃ digestion. APHA 3125B.
Na	g/m ³	0.021	ICP-MS after HNO ₃ digestion. APHA 3215 B.
NH ₄	g/m ³ -N	0.01	Filtered Sample. Colorimetry, Phenolhypochlorite. Discrete Analyser.
NO ₃ -N	g/m ³ -N	0.05	Ion chromatography. APHA 4110B
pH	pH	0.1	Measured in lab by meter. APHA Method 4500-H+ B.
SO ₄	g/m ³	0.5	Filtered sample.Ion chromatography APHA 4110B
TDS	g/m ³	2	Calculated from Electrical Conductivity
Temp.	DegC	0.1	Meter.Field measurement.
Zn (D)	g/m ³	0.001	Filtered, ICP-MS APHA 3125B
Zn	g/m ³	0.0011	ICP-MS after HNO ₃ digestion. APHA 3125B/US EPA 200.8

Appendix III: Groundwater sampling protocol Summary¹

Pre-sampling:

- Gather site sheets with specific instructions
- Prepare and check sampling equipment and bottles
- Calibrate probes – conductivity, temperature & DO as required
- Plan sample delivery and prepare field sheets

Sample collection:

- Confirm site details and update as required
- Check probe calibration and bottle labels
- Measure depth to water
- Calculate or check purge volume²
- Install pump if necessary³
- Commence pumping and measure conductivity and temperature using a flow cell
- Pump 3 annular volumes (or as otherwise specified & noted)
- Ensure temperature is stable within 0.2°C
- Ensure conductivity is stable within 3%
- Measure D.O. if required minimising aeration
- Note field parameters and sampling details on field sheet
- Collect samples in bottles labelled with site number and name
- All filtering will be carried out in the lab unless specified
- Microbial samples should retain a small air space⁴
- Clean and rinse all sampling equipment and leave site as before

Storage and delivery:

- Store sample bottles in chilli bin with ice or refrigerated container
- Keep sample bottles cool below 4°C but do not freeze microbial samples
- Samples should be delivered to the lab within 24 hours for microbial analysis and preferably for all analyses
- Chain of custody sheets should be provided and suite of analyses checked

Microbial specific:

- Take water level with sterilised probe
- Wear disposable sterile gloves
- Sterilise sample pump (if required to introduce) using 60-70% ethanol and take blank sample before sampling
- Tap/discharge end should be dried with sterile wipes and flamed
- Use sterile sample bottles with small air space
- Deliver cooled but unfrozen to lab within 24 hours

¹ For more information refer to document 1464180 however where different this summary should be followed

² $\pi r^2 \times$ saturated well depth – similar riser pipe volume e.g. 100 mm diameter well is ~ 8L per m; 50 mm diameter well is ~ 2L per m; see site sheets for detail and suggested purge volume

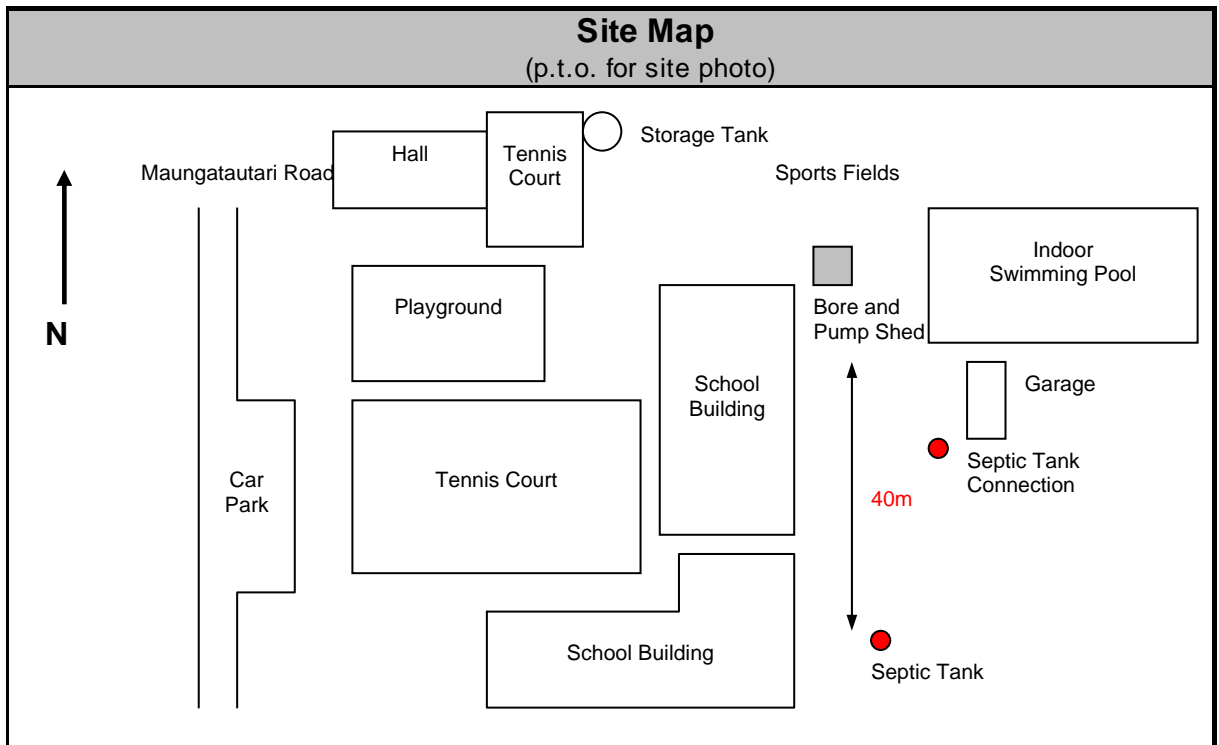
³ Pumping equipment introduced for microbial sampling must be sterilised

⁴ For further consideration of microbial sampling requirements see specific section below

Appendix IV: Example site sheets

SCHOOL WATER SUPPLY SITE DETAILS

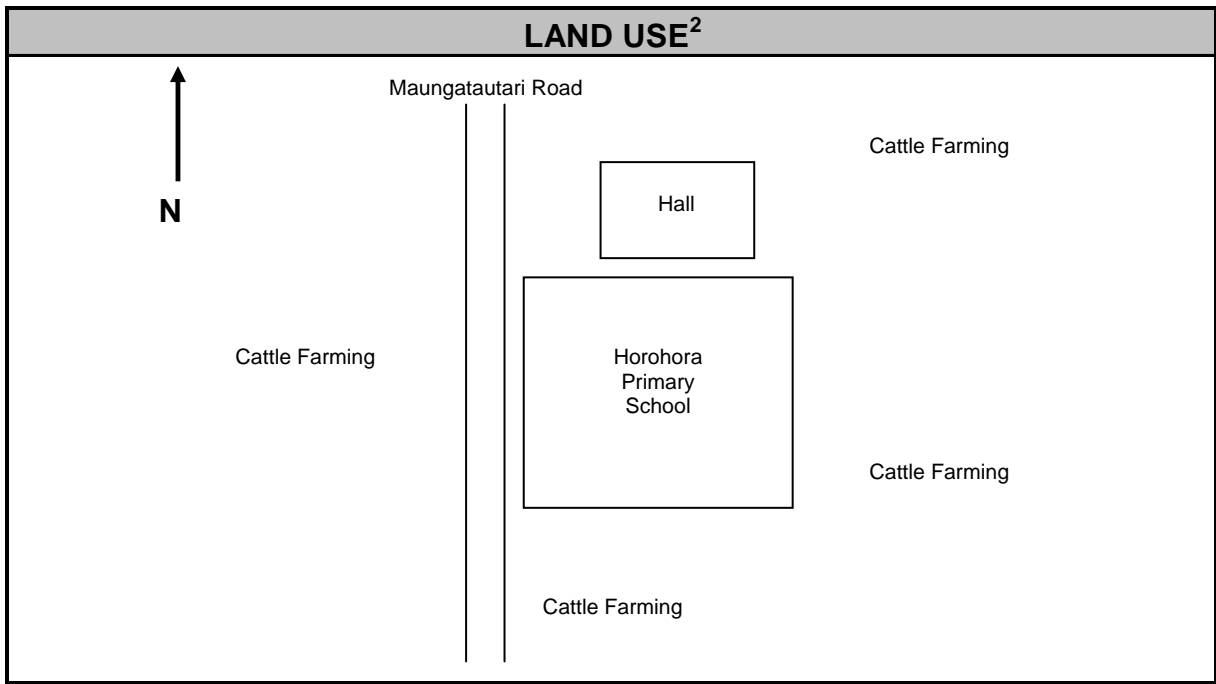
Site Name:	Hora Hora Primary	Site (Hydrol) No:	70.1156
Map Reference:	T15:408-546	Well No./Type:	7783
Address:	Maungatautari Road Horahora	Bore Log? (y/n)	Yes
Person to Contact:	Lyn (S)	Driller:	Rotorua
	(07) 827 2823	Year of Construction:	-
Number of People Served:	49 children	Depth (m):	28
Aquifer Geology:	Gravel	Diameter (mm):	150
Drastic Index:	141	Casing depth (m):	14
Registered Supply? (y/n)	Yes	Casing type:	100
Topography:	Strongly rolling	Pump details:	Deep well cylinder
Land Use:	Farming, gullies	Sample method:	Bore and office tap
		Sampling regime:	2 monthly (Medlab)
		Static water level (m):	4 (borelog) / 11 (00)
		Water Quality:	Good



COMMENTS¹
<p>Bore water is used for everything including drinking. No water treatment systems installed.</p> <p>To sample - attach plastic sheeting to the tap in the pump shed to divert water out of the shed. Turn the tap on, then flick the float switch on the storage tank in the trees on the hill to start the pump. Flush for 10 - 15 minutes and sample. Turn off the tap and reset float switch.</p>

OSH HAZARD IDENTIFICATION			
Hazards	Location	Risk	Action Required
Children	In driveway and carpark		Keep an eye out
Storage tank	In trees on the hill	Falling off and or in	Be careful

Notes: 1 Current Water Quality Sampling Regime, Sampling Method and Access



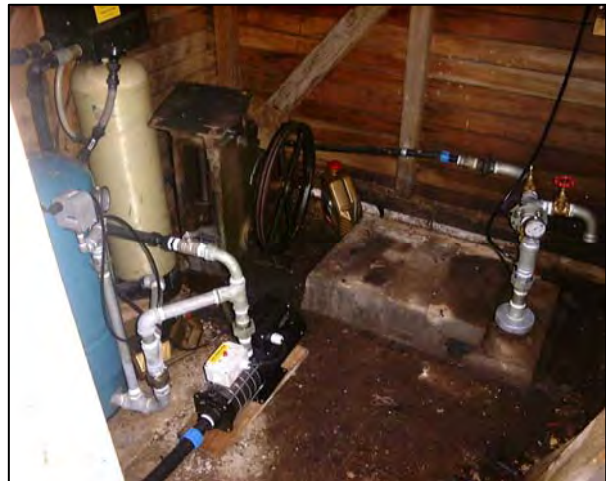
Notes: 2 Potential threats and details regarding distances.

Photograph numbers: 501 - 504 & 1073

501. Location of Pump shed



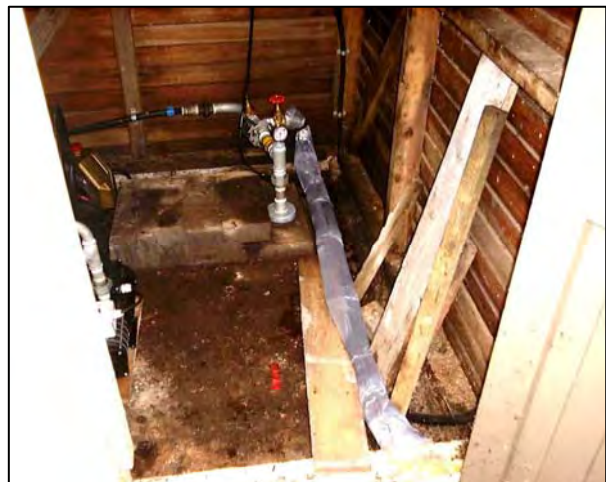
502. Pump and bore setup



504. Landuse and topography

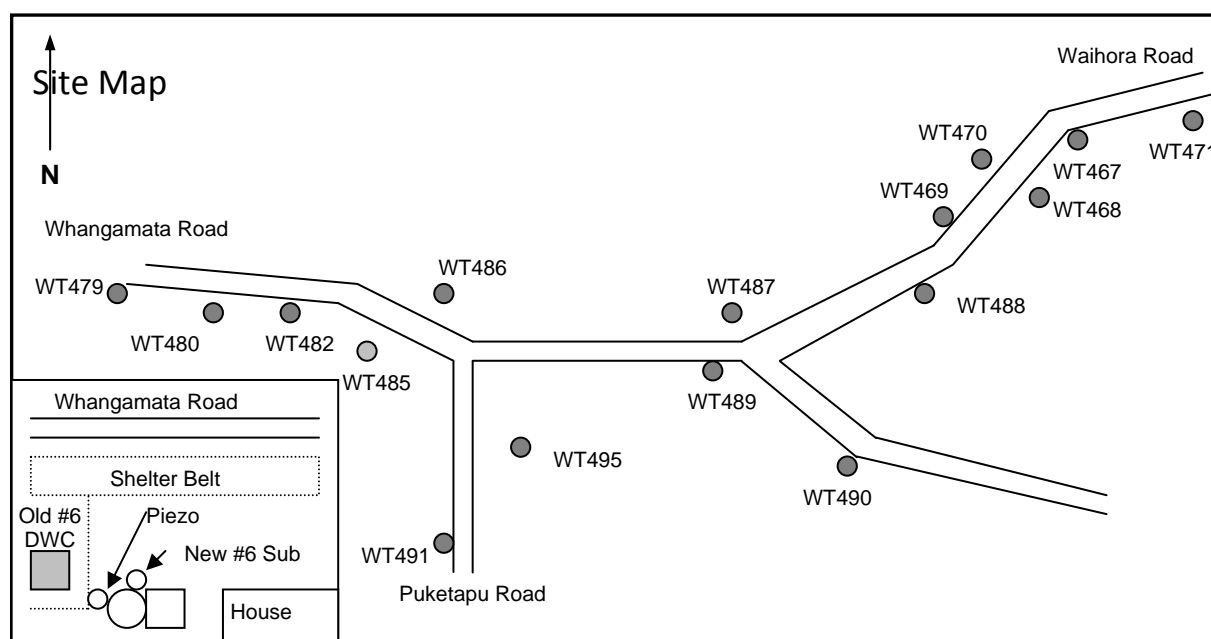


1073. Sampling technique



Lake Taupo groundwater site details

Site Name:	Waihora #6 New Production	Site (Hydrol) No:	72.514
Map Reference:	T17:546-844	Wells on property:	16
Address:	Whangamata Road RD1, Taupo	Bore log available?	Yes
Person to contact:	Peter Booth / Ken Burt	Driller:	Benton & Son
ph:	Ken: (025) 468224 Peter: (025) 945066	Year of Construction:	2001
Survey Date:	19/02/2002	Bore Depth (m):	171
Aquifer geology:	Rhyolite	Casing Diameter (mm):	100
Drastic Index:	-	Casing depth (m):	78
Topography:	Gently rolling	Casing type:	Steel
Land Use:	Sheep and beef	Screen diameter (mm)	-
Water Use:	Stock	Screen depths (m)	78 – 171
Level probe access (y/n)	Yes	Screen type:	-
Static water level (m chf)	8.095 (19/02/2002)	Pump details:	Submersible
Water quality comment:	High in manganese	Well yield (m³d⁻¹)	90
Water quality sampled	Yes	Drawdown for above	79.6
		Aquifer test info (y/n)	Yes
		Water supply?	Bore



Comments

New #6 is suitable for groundwater level monitoring, groundwater quality sampling and aquifer flow testing. Samples have high concentrations of manganese.

Appendix V: Selected MoH determinand data sheets

(Excerpted from Ministry of Health 2005a Guidelines for drinking water quality management in New Zealand)

Arsenic

Updated July 2005.

Maximum acceptable value (provisional)

Based on health considerations, the concentration of arsenic in drinking-water should not exceed 0.01 mg/L. The WHO guideline value is designated as provisional in view of the scientific uncertainties. The maximum contaminant level (USEPA 2004) is 0.01 mg/L.

Sources to drinking-water

1 *To source waters*

Arsenic can enter the aquatic environment by the weathering of minerals and rocks, run-off from soils, from geothermal fluids or atmospheric deposition. The mineralised zones of sulphitic ores probably contain the highest concentrations of arsenic although high levels of arsenic may also occur in some coals and peats. In New Zealand, arsenic occurs in greywacke and schists and in tertiary volcanics. In greywacke and schist it occurs as arsenopyrite and loellingite in gold-bearing lodes of the Reefton and Otago Goldfields. It also occurs in auriferous quartz lodes associated with volcanics in the Hauraki goldfield, especially in the Tokatea-Coromandel area. Geothermal fluids contain elevated concentrations of arsenic and water bodies such as the Waikato River subjected to their discharge have typically high arsenic concentrations.

Arsenic can also be released to the aquatic environment via the discharge of wastes from industries in which it is used. Arsenic and its compounds are used in the production of semiconductors, pigments, for medical purposes, in glassmaking, in alloys with lead and copper, rodenticides, insecticides, herbicides, and as timber preservatives.

2 *From treatment processes*

No known sources.

3 *From the distribution system*

No known sources, despite the use of arsenical brasses.

Forms and fate in the environment

The most common oxidation states of arsenic are +3 and +5 although it can also exist in the 0 and -3 states. Arsenic (V) is the stable form of arsenic in aerobic water while arsenic (III) is the predominant form of arsenic under anaerobic conditions such as in groundwaters. In surface waters, the majority of arsenic occurs in a soluble form which can be removed from the water by co-precipitation with hydrated iron and aluminium oxides, or adsorbed/chelated by suspended organic matter in water or humic substances in bottom sediments.

Typical concentrations in drinking-water

Arsenic was routinely measured in New Zealand drinking-water supplies as part of the Department of Health three yearly surveillance programme. Of 1895 samples analysed between 1983 and 1989, 13 samples (1.3% of supplies) had concentrations equal to or

exceeding the 1984 guideline value of 0.05 mg/L. The majority of drinking-water supplies in New Zealand have arsenic concentrations of less than 0.001 mg/L. However, supplies using source waters significantly contaminated with arsenic such as the Waikato River, that do not fully treat their water have been reported to contain up to 0.15 mg/L in reticulated water.

The P2 Chemical Determinand Identification Programme, sampled from 342 zones, found arsenic concentrations to range from 'not detectable' (nd) to 0.10 mg/L, with the median concentration being 'nd' (limit of detection = 0.001 mg/L).

Levels in natural waters generally range between 0.001 and 0.002 mg/L, although concentrations may be elevated (up to 12 mg/L) in areas containing natural sources (WHO 2004).

Removal methods

Conventional coagulation treatment with iron or aluminium can achieve good removal of arsenic. The effectiveness depends on: the oxidation state of the arsenic (trivalent arsenic should be converted to pentavalent arsenic by oxidation with chlorine or potassium permanganate); the pH at which the process is carried out; and whether iron or aluminium is used as the coagulant.

Lime-softening, ion exchange resins, and activated alumina can also be used to remove arsenic. The removal of arsenic from water by ion exchange and alumina depends upon the arsenic being present as the negatively-charged arsenate ion, AsO_4^{3-} . This ion contains arsenic in the highest oxidation state (5+), and oxidation of any arsenic in the 3+ oxidation state is required if it is to be removed by these two processes.

Analytical methods

Referee method

Electrothermal Atomic Absorption Spectrometric Method (APHA 3113).

Some alternative methods

- 1 Hydride Generation/Atomic Absorption Spectrometric Method (APHA 3114B).
- 2 Inductively Coupled Plasma – Mass Spectrometry (EPA Method 200.8).

Health considerations

The health considerations apply mainly to the inorganic arsenic compounds. These are more likely to be present in drinking-water supplies than the organic compounds. Except for individuals who are occupationally exposed to arsenic, the most important route of exposure is through the oral intake of food and beverages.

Ingested elemental arsenic is poorly absorbed and is largely eliminated unchanged. Soluble arsenic compounds are readily absorbed from the gastro-intestinal tract. Inorganic arsenic may accumulate in skin, bone and muscle. In humans, inorganic arsenic does not appear to cross the blood-brain barrier but transplacental transfer of arsenic has been reported.

Early symptoms of acute arsenic intoxication include abdominal pain, vomiting, diarrhoea, pain in the muscles, weakness and flushing of the skin. Signs of chronic arsenicalism include dermal lesions, peripheral neuropathy, skin cancer and peripheral vascular disease.

Arsenic does not appear to be mutagenic in bacterial and mammalian assays although it can induce chromosomal aberrations in a variety of cultured cell types, including human cells.

Arsenic has not been demonstrated to be essential in humans. It is an important drinking-water contaminant, as it is one of the few substances shown to cause cancer in humans through consumption of drinking-water. There is overwhelming evidence from epidemiological studies that consumption of elevated levels of arsenic through drinking-water is causally related to the development of cancer at several sites, particularly skin, bladder and lung. In several parts of the world, arsenic-induced disease, including cancer, is a significant public health problem. Because trivalent inorganic arsenic has greater reactivity and toxicity than pentavalent inorganic arsenic, it is generally believed that the trivalent form is the carcinogen. However, there remains considerable uncertainty and controversy over both the mechanism of carcinogenicity and the shape of the dose-response curve at low intakes. Inorganic arsenic compounds are classified by IARC in Group 1 (carcinogenic to humans) on the basis of sufficient evidence for carcinogenicity in humans and limited evidence for carcinogenicity in animals.

Derivation of maximum acceptable value

Data on the association between internal cancers and ingestion of arsenic in drinking-water are insufficient for quantitative assessment of risk. Instead, owing to the documented carcinogenicity of arsenic in the drinking-water of human populations, the lifetime risk of skin cancer has been estimated using a multistage model that is both linear and quadratic in dose. On the basis of observations in a Taiwanese population ingesting arsenic contaminated drinking-water, the levels associated with lifetime skin cancer risks of 10^{-4} , 10^{-5} and 10^{-6} are 1.7, 0.17 and 0.017 $\mu\text{g/L}$. These values may, however, overestimate the actual risk of skin cancer owing to the possible contribution of other factors to disease incidence in the Taiwanese population and to possible dose-dependent variations in the metabolism that could not be taken into consideration. Moreover, 1–14% of arsenic-induced skin cancers are fatal.

WHO has established a provisional guideline value of 0.01 mg/L for arsenic in drinking-water. The estimated lifetime skin cancer risk associated with exposure to this concentration is six per 10,000 (6×10^{-4} or $6 \times 10^{-6} - 8.4 \times 10^{-5}$ lifetime risk of fatal skin cancers).

The WHO provisional guideline value agrees with the value derived on the basis of the provisional maximum tolerable daily intake for inorganic arsenic of 2 $\mu\text{g/kg}$ body weight, established by the Joint FAO/WHO Expert Committee on Food Additives in 1983, and assuming a 20% allocation to drinking-water.

WHO stated in 2004 that there remains considerable uncertainty over the actual risks at low concentrations, and available data on mode of action do not provide a biological basis for using either linear or non-linear extrapolation. In view of the significant uncertainties surrounding the risk assessment for arsenic carcinogenicity, the practical quantification limit in the region of 0.001–0.01 mg/L and the practical difficulties in removing arsenic from drinking-water, the guideline value of 0.01 mg/L is retained. In view of the scientific uncertainties, the guideline value is designated as provisional.

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World Health Organization. 2004. *Guidelines for Drinking-water Quality* (3rd ed).

Boron

Updated July 2005.

Maximum acceptable value

Based on health considerations, the concentration of boron in drinking-water should not exceed 1.4 mg/L. In 2001 the Australian Drinking Water Guidelines considered that boron may be an essential trace element for humans and based on an acceptable range of oral intake, a concentration of up to 4 mg/L in water would not pose a human health risk.

Sources to drinking-water

1 To source waters

The most common boron containing mineral is tourmaline which is present in igneous and some sedimentary rocks. The weathering of both of these rock types releases boron, which is then transported in solution. Soil leaching and volcanic activity may also add boron to water. Boron has been found in hot springs and brines at high concentrations, indicating that hydrothermal and geothermal fluids are also a source of boron.

Boron may also be released to water from the discharge of industrial and domestic wastewaters, or in agricultural run-off. In industry, boron is used in fire retardants, borosilicate glass, enamels and antioxidants for soldering, detergents and in the photographic, cosmetic, leather, textile, paint and wood-processing industries. It is also used in the preparation of disinfectants and drugs and in some synthetic rocket fuels. Elemental boron is used to harden metals, in nuclear reactors for neutron absorption and in agriculture to improve crop yields.

2 From treatment processes

No known sources.

3 From the distribution system

No known sources.

Forms and fate in the environment

The chemical behaviour of boron in the aquatic environment is poorly understood, but it is thought that the predominant species is boric acid which is moderately soluble in water and does not dissociate readily.

Typical concentrations in drinking-water

Boron was routinely measured in New Zealand drinking-water supplies as part of the Department of Health three-yearly surveillance programme. Of 1904 samples analysed between 1983 and 1989, 35 samples (1.3% of supplies) contained concentrations equal to or exceeding the 1984 guideline value of 0.5 mg/L.

The P2 Chemical Determinand Identification Programme, sampled from 297 zones, found boron concentrations to range from 'not detectable' (nd) to 11 mg/L, with the median concentration being 'nd' (limit of detection = 0.06 mg/L).

Removal methods

There are, at present, no economically feasible methods of removing boron from source waters, other than changing the source. Boron concentrations can be reduced by granular activated carbon, anion exchange or lime-softening.

Analytical methods

Referee method

Colorimetric Method, Azomethine-H Parts C, D (Boron in Waters, Effluents, Sewage and Some Solids, 1980, HMSO, UK).

Some alternative methods

- 1 Colorimetric Method (APHA 4500-B B).

Health considerations

Boron, when administered as borates or boric acid, is rapidly and almost completely adsorbed from the gastrointestinal tract. Boron excretion occurs mainly through the kidney. Boron is present naturally in many food products, with high amounts found in foods of plant origin, especially fruits, leafy vegetables, nuts and legumes. It has been estimated that intake of boron from food is about 10 times that from water.

Long term exposure of humans to boron compounds leads to mild gastrointestinal irritation. In short-term and long-term animal studies and in reproductive studies with rats, testicular atrophy was observed. Boric acid and borates were not mutagenic in various *in vitro* test systems. No increased tumour incidence was observed in long-term carcinogenicity studies in mice and rats.

Acute boron poisoning has been reported after application of dressings, powders or ointments containing borax and boric acid to large areas of abraded skin and following ingestion. Symptoms of boron poisoning include gastrointestinal disturbances, skin eruptions, and central nervous system stimulation followed by depression.

Tests for mutagenicity using bacteria and mammalian cells have been mostly negative. Neither boric acid nor borate induce chromosomal aberrations in mammalian cells.

Derivation of maximum acceptable value

A tolerable daily intake approach has been used for the derivation of the MAV for boron in drinking-water. Benchmark dose methodology (based on the influence of boron of foetal body weight affecting 5 per cent of the animals, in a rat study) has been used to derive a tolerable daily intake value. This value has been used for the derivation of the MAV of boron in drinking-water.

The MAV for boron in drinking-water was derived as follows:

$$\frac{10.3 \text{ mg/kg body weight per day} \times 70 \text{ kg} \times 0.2}{2 \text{ L per day} \times 50} = 1.4 \text{ mg/L}$$

where:

- benchmark dose (5%) = 10.3 mg/kg body weight per day
- average weight of an adult = 70 kg
- the proportion of tolerable daily intake assigned to the consumption of water = 0.2
- uncertainty factor = 50
- average amount of water consumed by an adult = L per day.

NB: Here the benchmark dose is used in place of the NOAEL.

References

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World Health Organization. 2004. *Guidelines for Drinking-water Quality* (3rd ed).

Cadmium

Updated July 2005.

Maximum acceptable value

Based on health considerations, the concentration of cadmium in drinking-water should not exceed 0.004 mg/L (4 µg/L). The maximum contaminant level (USEPA 2004) is 0.005 mg/L.

Sources to drinking-water

1 To source waters

Cadmium can enter water from the weathering of rocks and minerals and run-off from soils. The only naturally-occurring cadmium compound of significance, the sulphide greenockite, CdS, which is fairly rare, is almost always associated with the polymetallic sulphide ores of zinc, lead and copper.

Cadmium has a wide range of sources and may enter water in industrial and domestic discharges or from street and agricultural run-off. Domestic discharges generally contain high levels of cadmium. Its principal industrial uses are in electroplating other metals or alloys for corrosion protection, in solders and in amalgam used in dentistry. It is also used in the manufacture of pigments, nickel-cadmium storage batteries, electronic equipment, lubricants, photography supplies, glass, ceramics, biocides and as a stabiliser in plastics. It is likely to be present in waste discharged from fertiliser factories using phosphate ores containing cadmium. In agriculture, farm run-off containing these fertilisers are an important source of diffuse pollution by cadmium. Exhaust emission and tyre wear contribute a significant amount of cadmium to street run-off.

2 From treatment processes

No known sources.

3 From the distribution system

Cadmium may enter drinking-water from the dissolution of galvanised pipes in which it is an impurity associated with the zinc. It may also be present as a result of cadmium-containing solders in fittings, water heaters, water coolers and taps.

Forms and fate in the environment

In fresh waters, cadmium exists principally as the free Cd(II) ion, cadmium chloride and cadmium carbonate. Adsorption is probably the most important process for removal of cadmium from the water column. Exchange of cadmium for calcium ions in the lattice structure of carbonate minerals can remove cadmium from solution. In natural waters, co-precipitation with hydrous iron, aluminium and manganese oxides occurs. Alternatively, in waters of high organic content, adsorption of cadmium to humic substances and other organic complexing agents can be significant.

Typical concentrations in drinking-water

Cadmium was routinely measured in New Zealand drinking-water supplies as part of the Department of Health three yearly surveillance programme. Typical concentrations of cadmium in New Zealand drinking-water supplies are <0.005 mg/L (<5 µg/L).

The P2 Chemical Determinand Identification Programme, sampled from 898 zones, found cadmium concentrations to range from 'not detectable' (nd) to 0.26 mg/L, with the median concentration being 'nd' (limit of detection = 0.0005 mg/L).

Removal methods

Lime-softening achieves good removal of cadmium, provided it is applied to hard waters.

Ion exchange resins can remove cadmium, provided the resins are not overwhelmed by other cations such as calcium and magnesium. This form of treatment may be useful for the removal of heavy metals that have entered the water post-treatment.

Adsorption of cadmium on to PAC, GAC and oxides of Mn(IV), Fe(III) and Al(III) has been reported.

Chemical coagulation with aluminium and iron salts is limited as a viable option for the removal of soluble cadmium. The effectiveness of removal is dependent on the pH at which the process is carried out. In both cases, the effectiveness increases with increasing pH.

In situations where the dissolution of poor-quality zinc from galvanized pipes is a source of cadmium, adjustment of the water chemistry to reduce its corrosiveness will minimise cadmium concentrations.

Analytical methods

Referee method

Electrothermal Atomic Absorption Spectrometric Method (APHA 3113).

Some alternative methods

- 1 Inductively Coupled Plasma (ICP) Method (APHA 3120).
- 2 Inductively Coupled Plasma – Mass Spectrometry (EPA Method 200.8).

Health considerations

Absorption of cadmium compounds is dependent on the solubility of the compounds. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of about 10–35 years.

The kidney is the main target organ for cadmium toxicity. In humans long-term exposure can cause kidney dysfunction leading to the excretion of protein in the urine. This may occur in about 10 per cent of the population if the amount of cadmium exceeds 200 mg/kg. Other effects may include the formation of kidney stones and softening of the bones (osteomalacia).

Itai-Itai disease has been reported in Japan among people exposed to cadmium via food and drinking-water. Symptoms were similar to osteomalacia accompanied by kidney dysfunction.

Evidence concerning the mutagenicity of cadmium is unclear with many tests reporting negative results although some report gene mutation and chromosome abnormalities in mammalian cells. However the positive results are reported as being weak and seen only at high concentrations.

There is evidence for the carcinogenicity of cadmium by the inhalation route, and the International Agency for Research on Cancer has classified cadmium and cadmium compounds in Group 2A (probably carcinogenic to humans). However, there is no evidence of carcinogenicity by the oral route. Food is the main source of daily exposure to cadmium. The daily oral intake is 0.01–0.035 mg. Smoking is a significant additional source of cadmium exposure.

Derivation of maximum acceptable value

As there is no evidence of carcinogenicity by the oral route and no evidence for the genotoxicity of cadmium, a provisional tolerable weekly intake (PTWI) approach has been used for the derivation of the MAV. Assuming an absorption rate for dietary cadmium of 5 per cent and a daily excretion rate of 0.005 per cent of body burden, the Joint FAO/WHO expert Committee on Food Additives concluded that, if levels of cadmium in the renal cortex are not to exceed 50 mg/kg, a total intake of cadmium should not exceed 0.001 mg/kg body weight per day. This total daily intake has been used to derive the MAV.

The MAV for cadmium in drinking-water was derived as follows:

$$\frac{0.001 \text{ mg/kg body weight per day} \times 70 \text{ kg} \times 0.1}{2 \text{ L per day}} = 0.0035 \text{ mg/L (rounded to 0.004 mg/L)}$$

where:

- PTWI = 0.007 mg/kg, so the tolerable daily intake = 0.001 mg/kg body weight per day
- average weight of an adult = 70 kg
- the proportion of tolerable daily intake assigned to the consumption of water = 0.1
- average amount of water consumed by an adult = 2 L per day.

References

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Manganese

Updated July 2005.

Maximum acceptable value

Based on health considerations, the concentration of manganese in drinking-water should not exceed 0.5 mg/L. Based on aesthetic considerations, the concentration of manganese in drinking-water should not exceed 0.04 mg/L. The USEPA has a secondary drinking water regulation of 0.05 mg/L for manganese.

Sources to drinking-water

1 To source waters

Manganese can reach the aquatic environment from the weathering of rocks and minerals and runoff from soils. Manganese is not an essential constituent of any of the more common silicate rock minerals, but it can substitute for iron, magnesium or calcium in silicate structures. Many igneous and metamorphic minerals contain manganese as a minor constituent. It is a significant constituent of basalt and many olivines and of pyroxene and amphibole. Small amounts are present in dolomite and limestone, substituting for calcium.

Manganese may enter water from industrial discharges and agricultural runoff. Manganese and its compounds are used in the steel industry in the manufacture of metal alloys, in the manufacture of dry cell batteries, paints, varnishes, inks, dyes, glass, ceramics, matches, fire works and fertilisers. Manganese is also used in animal feeds.

Bottom waters in lakes and reservoirs can become very low in dissolved oxygen. Under these conditions iron and manganese leach out from the sediments and begin to circulate through the water column, resulting in raw water concentrations that may be too high for the treatment process to handle. Uncontaminated rivers and streams generally have low concentrations of manganese, ranging from 0.001 mg/L to 0.6 mg/L.

2 From treatment processes

No known sources.

3 From the distribution system

There are situations in which manganese concentrations in the water at the consumers' taps can be higher than those entering the distribution system. This is not the result of manganese being dissolved from reticulation materials. It arises from manganese, in either soluble or insoluble form, passing into the distribution system. Insoluble manganese may settle out in pipes, and soluble manganese may be oxidized to insoluble forms, by oxygen or other chemical oxidants, such as chlorine, and also settle. Changes in water flows through the system may then resuspend the particulate manganese, which may lead to 'black' water at the consumers' taps.

Certain nuisance organisms concentrate manganese and give rise to taste, odour and turbidity problems in distributed water.

Forms and fate in the environment

Manganese has three valence states in natural environments (2+, 3+, 4+). In the absence of dissolved oxygen Mn(II) predominates, otherwise it is readily oxidised to Mn(IV). In natural oxygenated waters, a substantial fraction of manganese is present in suspended form. In surface waters, divalent manganese will be oxidised to manganese dioxide which will undergo sedimentation. In the presence of complex-forming inorganic and organic compounds, the colloidal stability of manganese oxides will be enhanced. Alternatively, in areas of low dissolved oxygen or in anaerobic areas

at low pH, soluble manganese forms may persist. Many of the groundwaters reported to carry large manganese concentrations are from thermal springs.

Typical concentrations in drinking-water

Manganese was measured routinely in New Zealand drinking-water supplies as an aesthetic parameter as part of the Department of Health three yearly surveillance programme. It is now classified as an inorganic parameter of health significance. Of 1143 samples analysed from 913 supplies between 1983 and 1989, 91 samples (9.3 per cent of supplies) were equal to or exceeded the highest desirable level (ie, GV) of 0.05 mg/L.

The P2 Chemical Determinand Identification Programme, sampled from 400 zones, found manganese concentrations to range from 'not detectable' (nd) to 1.7 mg/L, with the median concentration being 0.002 mg/L (limit of detection = 0.001 mg/L).

Removal methods

Oxidation of Mn(II) to insoluble Mn(IV) compounds is a commonly employed technique. Aeration uses oxygen from the air to achieve oxidation. This precipitates the manganese, which is either allowed to settle or is removed by filtration. The rate at which oxidation occurs is pH dependent, becoming faster as the pH is increased. Some Mn(II) is adsorbed on to higher oxidation states of Mn in slightly alkaline solution. A coating of higher oxides of manganese on filter granules acts to catalyse the removal of lower oxidation states. Organically-bound manganese is not removed by aeration.

Other oxidising agents such as chlorine and potassium permanganate may be used for the removal of manganese. A pH of 8 is required for chlorine oxidation, and pH 7 to 8 is optimum for permanganate oxidation.

Sand or anthracite filters can be used to filter the precipitated manganese from the water. Before the removal process becomes efficient, a coating of iron and manganese oxides must develop on the grains of the filter medium. Until this coating develops, removal may be poor. Natural zeolites (ion exchange materials) treated with manganese can be used as the filter medium. This medium is known as greensand, and requires periodic regeneration of the iron and manganese oxide coating. Mn(II) ions come into contact with the zeolite and are converted to the insoluble oxide which is filtered out by the filter bed.

Natural zeolites or synthetic resins can also be used to remove manganese by a true ion-exchange process. Sodium attached to the zeolite is exchanged for Mn(II) ions in the incoming water. It is important that the water is free of oxygen that might lead to oxidation and precipitation of the manganese, as this will foul the zeolite.

Manganese, in the absence of oxygen, can be removed effectively by raising the pH above approximately 10 to precipitate manganese hydroxide. This can be exploited if the lime-soda ash process is being used for hardness reduction.

Analytical methods

Referee method

Electrothermal Atomic Absorption Spectrometric Method (APHA 3113).

Some alternative methods

- 1 Flame Atomic Absorption Spectrometric Method (APHA 3111).
- 2 Inductively Coupled Plasma Method (APHA 3120B).
- 3 Inductively Coupled Plasma – Mass Spectrometry (EPA Method 200.8).

Health considerations

Manganese is an essential trace element with an estimated daily nutritional requirement of 30–50 µg/kg body weight. The greatest exposure to manganese is usually from food. Its absorption rate can vary considerably according to actual intake, chemical form, and presence of other metals such as iron and copper. Typically, only about 3–8 per cent of ingested manganese is absorbed by the gastro-intestinal tract. In infants and young animals, very high absorption rates of manganese have been observed. After absorption it is concentrated in the liver and eventually excreted in faeces. It has a relatively short biological half-life of 13 to 37 days in humans. Manganese deficiency affects bone, the brain and reproduction in a number of species.

Evidence of manganese neurotoxicity has been seen in miners following prolonged exposure to manganese dusts. There is no convincing evidence of toxicity in humans associated with the consumption of manganese in drinking-water, but there are only limited studies available. By the oral route, manganese is often regarded as one of the least toxic elements.

In one case, the symptoms associated with consuming drinking-water containing a manganese concentration of close to 28 µg/L included lethargy, increased muscle tone, tremor and mental disturbances. However, the concentrations of other metals were also high and the reported effects may not be due to manganese alone.

Experiments with animals have shown no adverse effects, other than a change in appetite and a reduction in the metabolism of iron in haemoglobin synthesis. Some *in vitro* studies have reported mutagenic activity for manganese on mammalian cells and bacteria.

There is no firm evidence that manganese is carcinogenic. Some studies indicate that it may, in fact, have an anti-carcinogenic effect.

Derivation of maximum acceptable value

The MAV for manganese in drinking-water is based on the upper range value of manganese intake of 11 mg/day, identified using dietary surveys, at which there are no observed adverse effects (ie, considered a NOAEL), using an uncertainty factor of 3 to take into consideration the possible increased bioavailability of manganese from water. This results in a TDI of 0.06 mg/kg of body weight. The MAV was derived as follows:

$$\frac{0.06 \text{ mg/kg body weight per day} \times 70 \text{ kg} \times 0.2}{2 \text{ L per day}} = 0.42 \text{ mg/L (rounded to 0.4 mg/L)}$$

where:

- tolerable daily intake = 0.06 mg/kg body weight per day
- average adult weight = 70 kg
- the proportion of tolerable daily intake assigned to the consumption of water = 0.2
- average amount of water consumed per day = 2 L per day.

The aesthetic guideline value for manganese is 0.1 mg/L due to the fact that it deposits in water mains and causes discoloration when scoured out. Some water supplies may need to aim for a lower concentration to prevent the build-up.

At concentrations exceeding 0.1 mg/L, manganese can impart an undesirable taste to water.

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Nitrate and nitrite

Updated July 2005.

Maximum acceptable value for nitrate (short-term)

Based on health considerations, the concentration of nitrate (as NO_3^-) in drinking-water should not exceed 50 mg/L.

Maximum acceptable value for nitrite (short-term)

Based on health considerations, the short-term concentration of nitrite (as NO_2^-) in drinking-water should not exceed 3 mg/L.

Maximum acceptable value for nitrite (long-term and provisional)

Based on health considerations, the long-term concentration of nitrite (as NO_2^-) in drinking-water should not exceed 0.2 mg/L. The WHO guideline value for chronic effects of nitrite is considered provisional owing to uncertainty surrounding the relevance of the observed adverse health effects for humans and the susceptibility of humans compared with animals.

Maximum acceptable value for combined nitrate plus nitrite

The sum of the ratios of the concentrations of each to its Maximum acceptable value (short-term) should not exceed 1. The maximum contaminant level for nitrate (USEPA 2004) is 10 mg/L as N, and 1 mg/L for nitrite as N, or a total of 10 mg/L.

Sources to drinking-water

1 To source waters

Nitrate and nitrite can enter the aquatic environment from the oxidation of vegetable and animal debris and animal excrement.

Nitrate and nitrite can also enter water from agricultural, domestic and industrial discharges. Nitrate is used in chemical fertilisers, oxidising agents in the chemical industry, in the manufacture of glass, enamels for pottery, matches, pickling meat and in the production of explosives. A major source of nitrate is from municipal wastewaters and septic tanks. Nitrite is also used as a corrosion inhibitor in industry, and for curing meats.

2 From the treatment processes

The chlorination of raw waters containing significant amounts of ammonia or nitrite may lead to increases in nitrate through their oxidation. As 70 per cent or more of the chlorine consumed during the oxidation of ammonia leads to N_2 production, the increase in nitrate concentrations is likely to be small unless ammonia concentrations are high.

3 From the distribution system

Chloramination may give rise to the formation of nitrite within the distribution system if the formation of chloramine is not sufficiently controlled. The formation of nitrite is as a consequence of microbial activity and may be intermittent. Nitrification in distribution systems can increase nitrite levels, usually by 0.2–1.5 mg/L.

Forms and fate in the environment

Nitrate and nitrite are naturally occurring ions which make up part of the nitrogen cycle. Nitrate is the oxidised form of combined nitrogen found in natural waters and in dilute aqueous solutions is chemically unreactive. Under anaerobic conditions nitrate may be reduced to nitrite and ammonia. Nitrite is seldom present in surface waters at significant concentrations but may be present in ground waters. High nitrite levels are generally indicative of contamination. Incomplete nitrification of ammonia and

denitrification of nitrate result in the biochemical production of nitrite which is generally present only under anaerobic conditions.

Typical concentrations in drinking-water

Nitrate

Nitrate was routinely measured in New Zealand drinking-water supplies as part of the Department of Health three yearly surveillance programme. Of 1908 samples analysed between 1983 and 1989, 14 samples (0.7%) contained concentrations equal to or exceeding the 1984 MAV of 10 mg/L (N).

The P2 Chemical Determinand Identification Programme, sampled from 673 zones, found nitrate concentrations to range from 'not detectable' (nd) to 30 mg/L as NO₃-N, with the median concentration being 0.2 mg/L (limit of detection = 0.1 mg NO₃-N/L).

Nitrite

Nitrite was not measured routinely in New Zealand drinking-water supplies as part of the Department of Health three yearly surveillance programme.

The P2 Chemical Determinand Identification Programme, sampled from 227 zones, found nitrite concentrations to range from 'not detectable' (nd) to 0.088 mg/L, with the median concentration being 'nd' (limit of detection = 0.005 NO₂-N mg/L).

Removal methods

Nitrate

Nitrate is not removed from water by classical methods of treatment. Ion exchange systems have been developed for removing nitrate, but dilution with water of lower nitrate concentration from another source is commonly used, where one is available.

Nitrite

Treatment of the water with an oxidising agent such as chlorine will convert the nitrite to nitrate. The nitrate can then be treated as explained for nitrate. The USEPA Maximum Concentration Level for nitrite indicates that the concentration at which it might be of concern is ten times less than the guideline for nitrate. The oxidation of high nitrite levels to nitrate therefore will not create an unacceptably high nitrate concentration in the water, unless the nitrate level is already high, or the nitrite level is extremely high.

Analytical methods

Nitrate

Referee method

Cadmium Reduction Method (APHA-NO₃-E).

Some alternative methods

- 1 Ion Chromatography Method (APHA 4110).
- 2 Nitrate Electrode Method (APHA 4500-NO₃ D).

Nitrite

Referee method

Colorimetric Method (APHA 4500-NO₂ B).

Some alternative methods

1 Ion Chromatography Method (APHA 4110).

Health considerations

Ingested nitrate is absorbed readily and completely from the upper small intestine. Nitrite may be absorbed directly from the stomach as well as from the small intestine. Sodium nitrite is used as a food preservative, especially in cured meats.

The toxicity of nitrate in humans is thought to be due solely to its reduction to nitrite. The primary health concern regarding nitrate and nitrite is the formation of methaemoglobinaemia, so-called blue-baby syndrome. Nitrate is reduced to nitrite in the stomach of infants, and nitrite is able to oxidise haemoglobin (Hb) to methaemoglobin (metHb), which is unable to transport oxygen around the body. The reduced oxygen transport becomes clinically manifest when metHb concentrations reach 10% or more of normal Hb concentrations; the condition, called methaemoglobinaemia, causes cyanosis and, at higher concentrations, asphyxia. The normal metHb level in infants under three months of age is less than 3%. Other susceptible groups include pregnant women and people with a deficiency of glucose-6-phosphate dehydrogenase or methaemoglobin reductase. Methaemoglobinaemia in infants also appears to be associated with simultaneous exposure to microbial contaminants (eg, Addison and Benjamin 2004).

Nitrate is not mutagenic in bacteria and mammalian cells in vitro. Chromosomal aberrations were observed in the bone marrow of rats after oral nitrate uptake, but this could have been due to exogenous N-nitroso compound formation. Nitrite is mutagenic.

The weight of evidence is strongly against there being an association between nitrite and nitrate exposure in humans and the risk of cancer.

Derivation of maximum acceptable values

Nitrate (short-term)

The MAV of 50 mg/L (as NO₃) is to protect against methaemoglobinaemia in bottle-fed infants (short-term exposure). In epidemiological studies, methaemoglobinaemia was not reported in infants in areas where drinking-water consistently contained less than 50 mg of nitrate per litre.

The epidemiological evidence for an association between dietary nitrate and cancer is insufficient, and the MAV for nitrate in drinking-water is established solely to prevent methaemoglobinaemia, which depends upon the conversion of nitrate to nitrite. Although bottle-fed babies are the most susceptible, occasional cases have been reported in some adult populations.

Nitrite (short-term)

The short-term MAV of 3 mg/L (as NO₂) is to protect against methaemoglobinaemia in bottle-fed infants. Animal studies were inappropriate to establish a firm no observable adverse effect level for methaemoglobinaemia in rats. Therefore, a pragmatic approach was followed, accepting a relative potency for nitrite and nitrate with respect to methaemoglobin formation of 10:1 (on a molar basis), and a provisional MAV of 3 mg/L has been adopted for nitrite.

Nitrite (long-term)

The 0.2 mg/L (as NO₂) MAV for long-term exposure for chronic effects of nitrite is considered provisional owing to uncertainty surrounding the relevance of the observed adverse health effects for humans and the susceptibility of humans compared with animals. The occurrence of nitrite in the distribution system as a consequence of chloramine use will be intermittent, and average exposures over time should not exceed the provisional MAV. The nitrite MAV (long-term exposure) is based on allocation to drinking-water of 10% of JECFA ADI of 0.06 mg/kg of body weight per day, based on nitrite-induced morphological changes in the adrenals, heart and lungs in laboratory animal studies.

Nitrate : nitrite ratio

Because of the possibility of simultaneous occurrence of nitrite and nitrate in drinking-water, the sum of the ratio of the concentration of each to their short-term MAVs, as shown in the following formula, should not exceed 1:

$$\frac{C(\text{NO}_2)}{\text{MAV}(\text{NO}_2)} + \frac{C(\text{NO}_3)}{\text{MAV}(\text{NO}_3)} \leq 1$$

where C = concentration, and MAV = maximum acceptable value.

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