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REGIONAL COUNCIL

Annual soil quality monitoring report for the Wellington region, 2007/08

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1. Introduction

The soil ecosystem has multiple roles in the environment, including maintenance of productivity, habitat provision and acting as a buffer to pollution of adjacent water resources. Soil in the Wellington region is used to support a wide range of land uses including market gardens, horticulture, viticulture, dairy farming, drystock farming and forestry. Land use practices such as overstocking and over-cultivation can result in a long-term reduction in soil quality. Poor soil quality can produce lower agricultural yields, a less resilient soil and land ecosystem, and increase contamination of adjacent water bodies (NLMF 2007). Greater Wellington Regional Council (Greater Wellington) monitors the health of our region’s high quality soils to ensure that the effects of land use on soil quality are no more than minor.

This report summarises the results of soil quality monitoring undertaken at 23 drystock farming sites over the period 1 July 2007 to 30 June 2008. A report containing a detailed analysis of long-term trends in soil quality is produced every six years (see Croucher 2005).

2. Overview of the soil quality monitoring programme

2.1 Background

Greater Wellington became involved in a national soil quality programme known as "The 500 Soils Project" in 2000. After completion of the 500 soils project in 2001 Greater Wellington implemented a soil quality monitoring programme to continue monitoring the quality of soils in the Wellington region. As part of the 500 Soils Project a standard set of sampling methods, as well as physical, chemical and biological properties were identified. A value or ranges of values for each of the properties were derived enabling the relationship between the qualitative measure of the soil attribute and its soil quality rating to be determined. The use of these standard methods and properties allows comparisons of similar soils and land uses both within the region and nationally. These sampling methods and properties were adopted for use in Greater Wellington's soil quality monitoring programme.

2.2 Monitoring objectives

The objectives of Greater Wellington's soil quality monitoring programme are to:

- Provide information on the physical, chemical and biological properties of soils;
- Provide an early-warning system to identify effects of primary land uses on long-term soil productivity;
- Track specific, identified issues relating to the effects of land use on long-term soil productivity;
- Assist in the detection of spatial and temporal changes in soil quality; and
- Provide a mechanism to determine the effectiveness of policies and plans.

2.3 Monitoring sites and methods

The monitoring programme currently consists of 118 sites on the high quality soils across the region under different land uses (Figure 2.1). The frequency of sampling is dependent on the intensity of the land use; dairying, cropping and market garden sites are sampled every 3-4 years, drystock, horticulture and exotic forestry sites are sampled every 5-7 years, while native forest sites are sampled every 10 years. In the sampling period 2007/08, 23[1] pastoral sites all used for drystock farming were sampled (Figure 2.1, Appendix 1).

[1] Site GW066 was incorrectly located and while results identified by this site number are included in this report, the results are considered erroneous and therefore have not been recorded in our database.

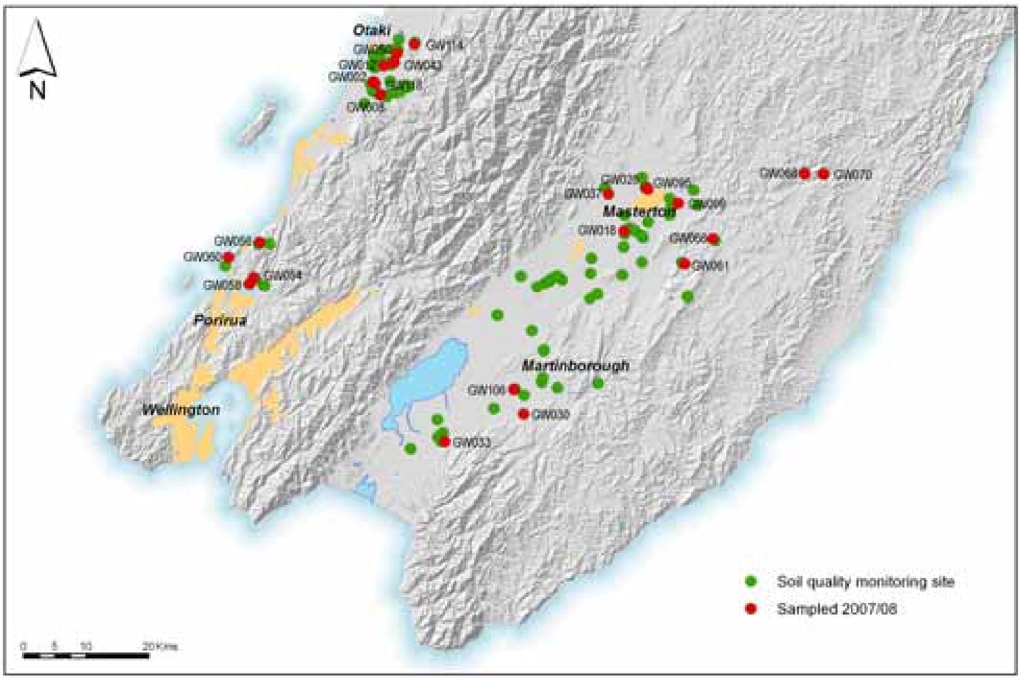

Figure 2.1: Location of Greater Wellington's soil quality monitoring sites

At each site three core samples are collected to establish the physical properties, while a composite of samples taken along a transect is used to determine the chemical and biological properties of the soil. A more detailed description of the sampling and laboratory methods used can be found in Appendix 2.

2.4 Monitoring variables

Seven primary soil properties as well as heavy metals were measured to assess soil quality (Table 2.1). Soil physical condition was assessed from the dry bulk density and macro-porosity measured using -10 kPa volumetric water content. These soil physical measurements also provide measures of the total porosity and particle density. Chemical and biological characteristics were assessed by the soil pH, total carbon (C) content, total nitrogen (N) content, mineralisable N, Olsen P, and derived measurements such as the C:N ratio. Total recoverable arsenic, cadmium, chromium, copper, lead, nickel and zinc were measured to assess the levels of heavy metals in the soil.

The soil properties themselves do not measure soil quality, rather soil quality is a value judgement about how suitable a soil is for its particular land use. A group of experts in soil science developed soil response curves for each of the soil properties for different soil order and land use combinations (Croucher 2005). Consequently different target values for properties are required for different land uses. For example, acidic soils with pH <5 may be of suitable quality to grow radiata pine, but not for a good crop of white clover (Croucher 2005).

Table 2.1: Indicators used for soil quality assessment

Indicator	Soil quality information
Physical properties	
Dry bulk density	The weight of soil. A measure of soil compaction and used for volumetric conversions.
Macroporosity	Measure of the larger voids in the soil. Indication of soil compaction, root environment and aeration.
Chemical properties	
pH	The acidity or alkalinity of soil, which controls the availability of many nutrients to plants. Is greatly influenced by the application of lime and fertilisers.
Total C content	The amount of organic matter. Helps to retain moisture and nutrients, and gives good soil structure.
Total N content	The amount of nitrogen contained in the organic matter reserves.
Olsen P	The amount of phosphorus that is available to plants, which is greatly affected by fertiliser additions. Essential nutrient for plants.
Heavy metals	Concentrations of total recoverable arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn).
Biological properties	
Potential mineralisable N	The amount of organic nitrogen that is available to plants. Also a measure of the activity of soil organisms which convert the nitrogen to forms plants can use.

3. Soil quality results

The majority of the 23 pastoral soil sites under drystock farming were found to be in good condition, with just four sites having more than one soil quality indicator outside the target (optimal) range (Figure 3.1). However, some sites were found to have low macroporosity values (indicating soil compaction) and suboptimal nutrient levels (high total N and variable Olsen P). These findings mirror many trends seen in other region's drystock soils (Stevenson 2008). The full results of the 2007/08 soil quality monitoring can be found in Appendix 3.

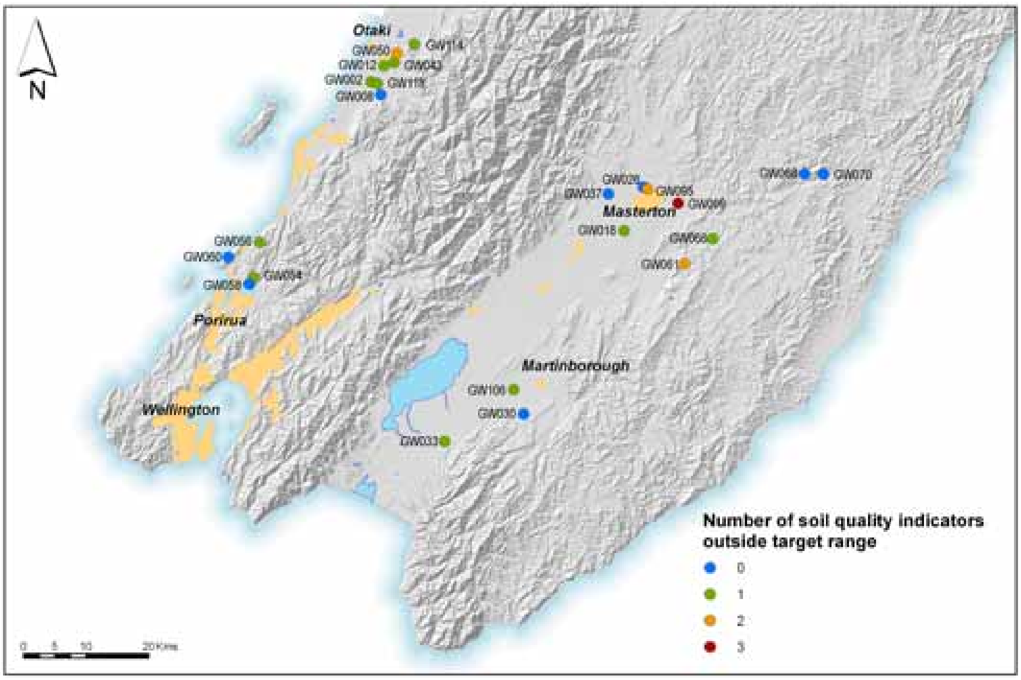

Figure 3.1: Number of soil quality indicators outside target ranges for each of the sites sampled in 2007/08

3.1 Physical properties

The physical properties measured determine the weight, porosity and size of the soil and its particles. The properties measured were bulk density, particle density and water release characteristics, which provide information on total porosity, macroporosity, total available water and readily available water.

Bulk density and macroporosity are both measures of soil compaction. Bulk density is the weight of a standard volume of soil, while macroporosity is a measure of the larger voids in the soil and indicates the ability of the soil to supply air to the roots (SINDI 2008). Compaction is caused by either animal treading, the impact of heavy machinery, cultivation, the loss of organic matter and subsequent desiccation, or a combination of some of these factors. Compacted soils will not allow water or air to penetrate, do not drain easily and restrict root growth. Macropores are important for air penetration into soil, and are the first pores to collapse when soil is compacted (NLMF 2007).

Of the 23 sites sampled, all had optimal bulk density values (Figure 3.2). However, eight sites (GW018, GW033, GW043, GW050, GW095, GW099, GW106 and GW114) were found to have low macroporosity (Figure 3.3).

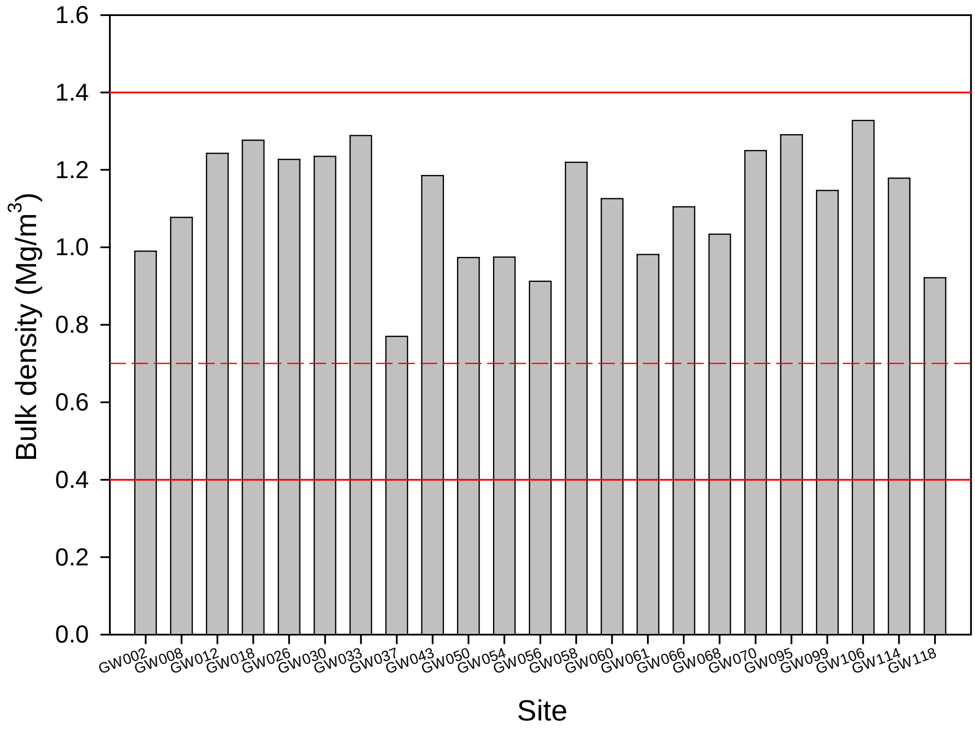

Figure 3.2: Bulk density at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range*.

* The lower threshold values for bulk density are 0.4 for pallic and recent soils, and 0.7 for all other soils.

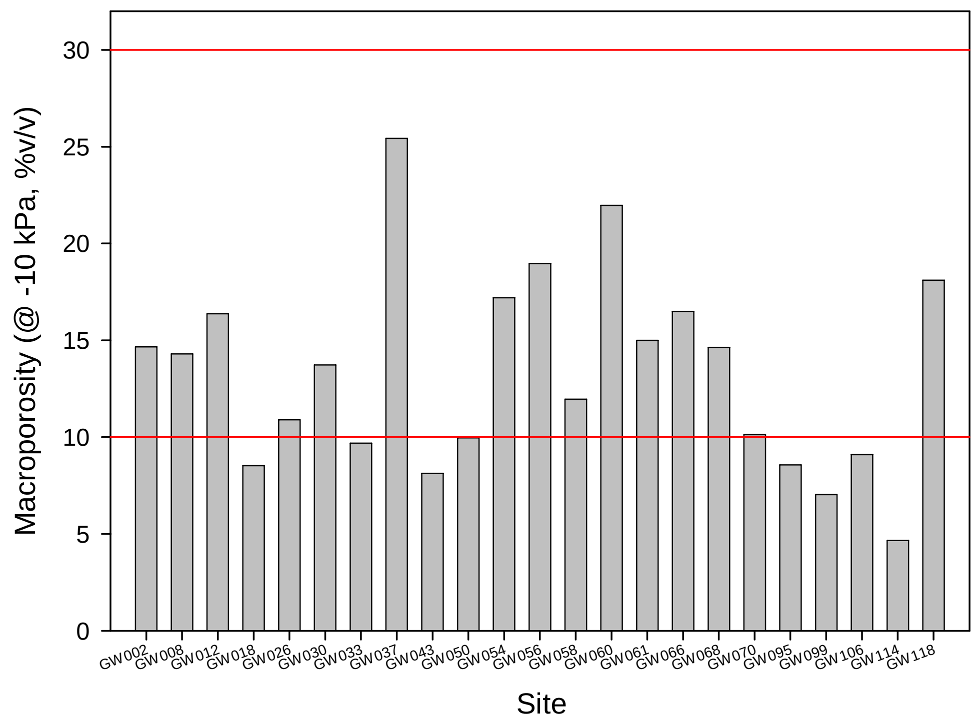

Figure 3.3: Macroporosity at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range.

3.2 Chemical properties

The chemical properties measured include pH, total carbon, total nitrogen and Olsen P. These chemical properties measure the acidity of the soil and the concentration of those elements associated with soil fertility (Croucher 2005).

Most plants and soil organisms have an optimum soil pH range for growth. Indigenous species are generally tolerant of acid conditions but introduced pasture and crop species require a more alkaline soil (NLMF 2007). A common farming practice is to add limestone ($CaCO_3$) to reduce the acidity of the soil, while the application of fertilisers containing ammonium or urea speeds up the rate at which acidity develops. The decomposition of organic matter also adds to soil acidity. All the sites had soil pH values within the target range, apart from site GW099 which had a slightly high pH (alkaline) (Figure 3.4).

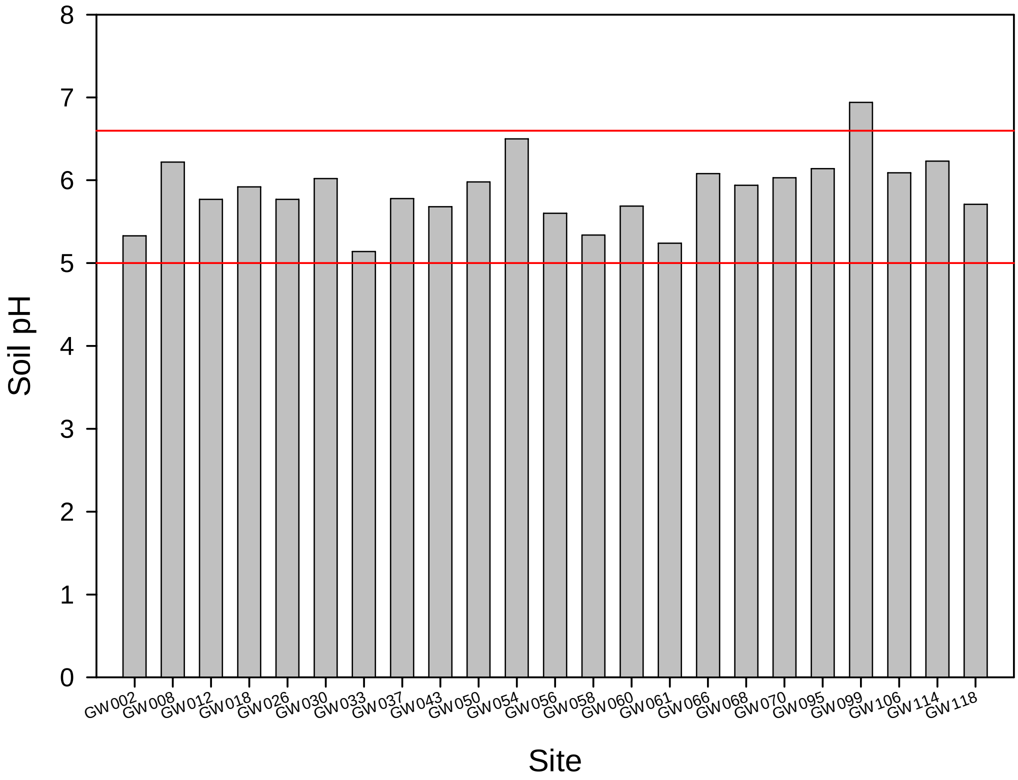

Figure 3.4: Soil pH at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range.

The total carbon content indicates the amount of organic matter in the soil which helps soils retain moisture and nutrients, and gives good soil structure for water movement and growth (NLMF 2007). Carbon content of soils can be reduced through the erosion of topsoil, however, the total carbon contents of the 23 sites were all found to be within the optimal range (Figure 3.5).

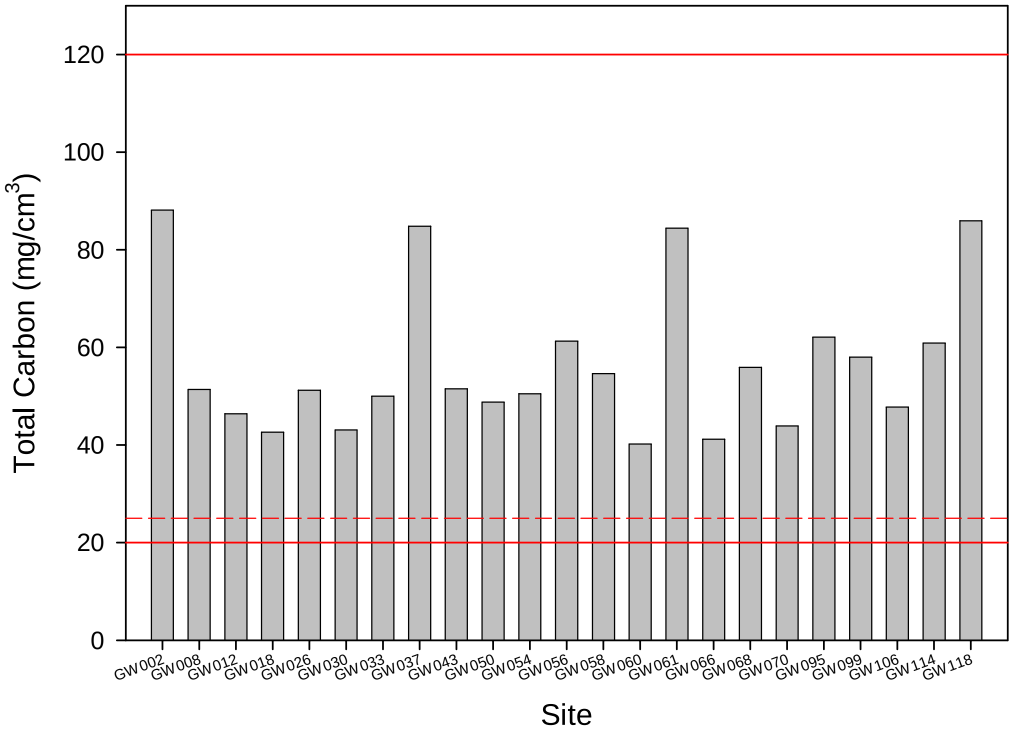

Figure 3.5: Total carbon content at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range*.

* Recent soils have a slightly higher low threshold value (red dashed line) than all other soil orders except organic.

Nitrogen (N) is an essential nutrient for plants and animals. Most N in soil is found in organic matter and total N gives a measure of those reserves. Twenty out of the 23 sites had total N contents within the optimal range, while sites GW002, GW061 and GW118 were found to have high total N contents (Figure 3.6). While nitrogen is essential for pasture productivity, there is a risk that when supply exceeds demand (when saturation is reached) any excess soluble nitrogen can be leached from the soil and adversely affect the quality of the underlying groundwater (MfE 2007).

Phosphorus (P) is an essential nutrient for plants and animals. Plants get their P from phosphates in the soil, and the plant available phosphate is measured as Olsen P. Many soils in New Zealand have low available phosphorus and P needs to be added for agricultural use (NLMF 2007). Of the 23 sites sampled, two sites (GW095 and GW099) had high Olsen P, while five had low Olsen P values (Figure 3.7).

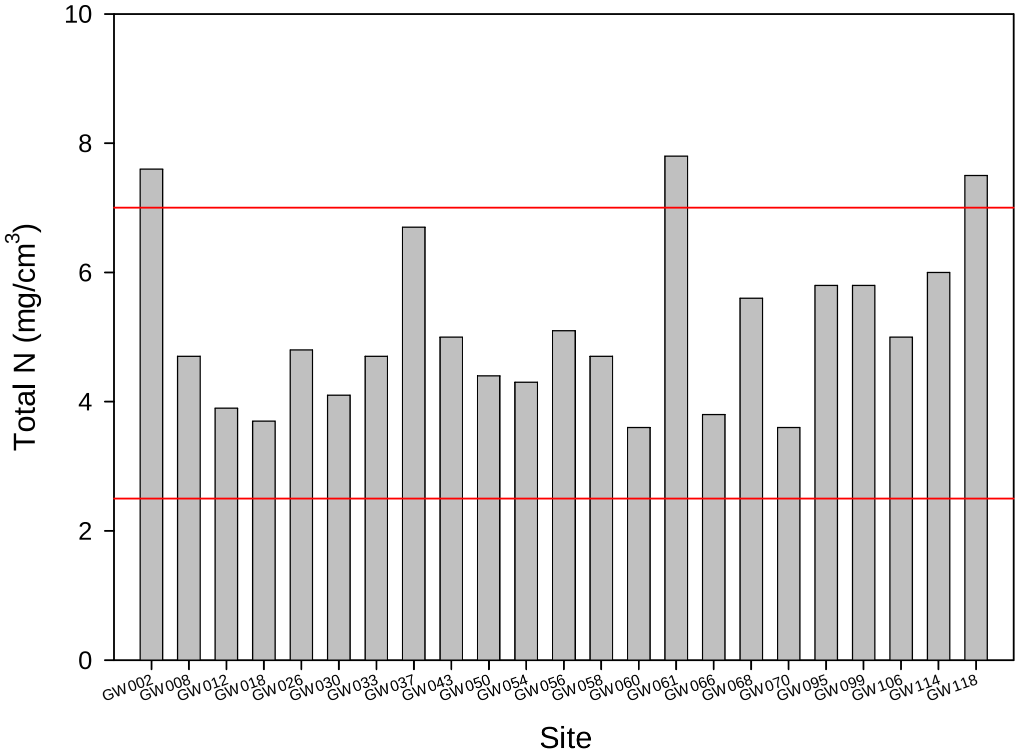

Figure 3.6: Total nitrogen content at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range.

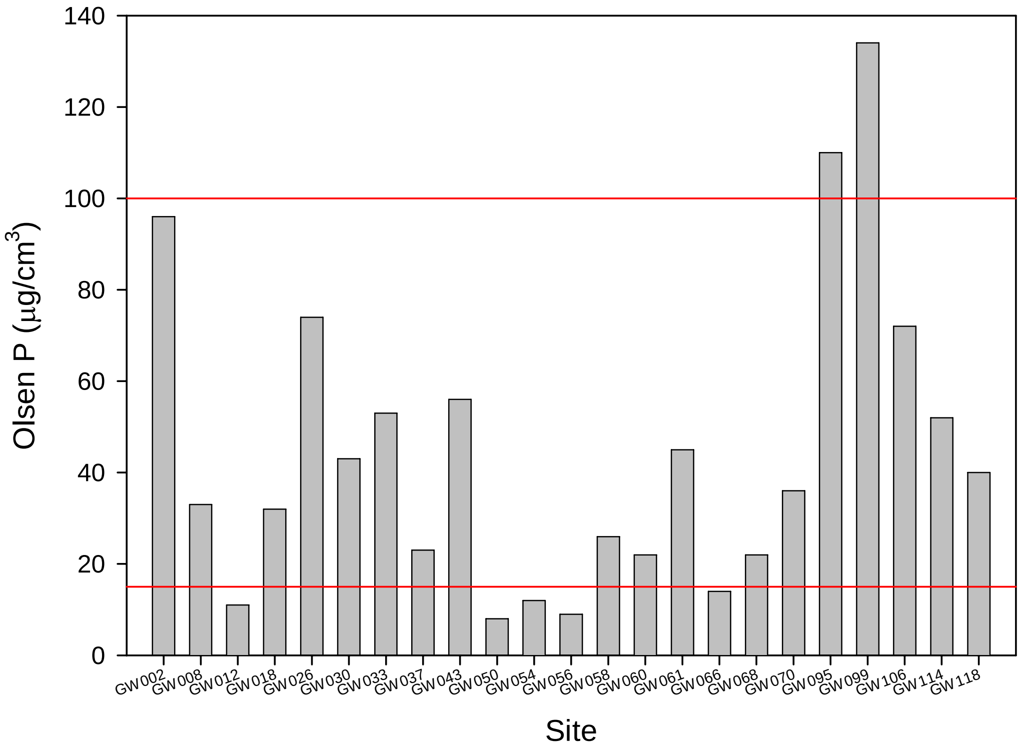

Figure 3.7: Olsen P values at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range.

A range of heavy metals including total recoverable arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni) and zinc (Zn) were measured to determine soil contaminant levels. Heavy metals occur naturally and the natural concentrations of most metals can vary greatly depending on geologic parent material (Stevenson 2008). However, heavy metals can also accumulate in the soil through a number of anthropogenic sources such as pesticides, insecticides, application of effluent, as well as the application of phosphate fertilisers.

The concentrations of total recoverable heavy metals found at all 23 drystock sites are shown in Figure 3.8. Apart from the arsenic concentration found at the site incorrectly located as site GW066[2], all metal concentrations were well below the NZWWA (2003) guidelines (Table 3.1).

Table 3.1: Guideline values for heavy metal concentrations in soil, adapted from NZWWA (2003)

Heavy metal	Soil limit (mg/kg)
Arsenic (As)	20
Cadmium (Cd)	1
Chromium (Cr)	600
Copper (Cu)	100
Lead (Pb)	300
Nickel (Ni)	60
Zinc (Zn)	300

[2] Refer to footnote on page 2.

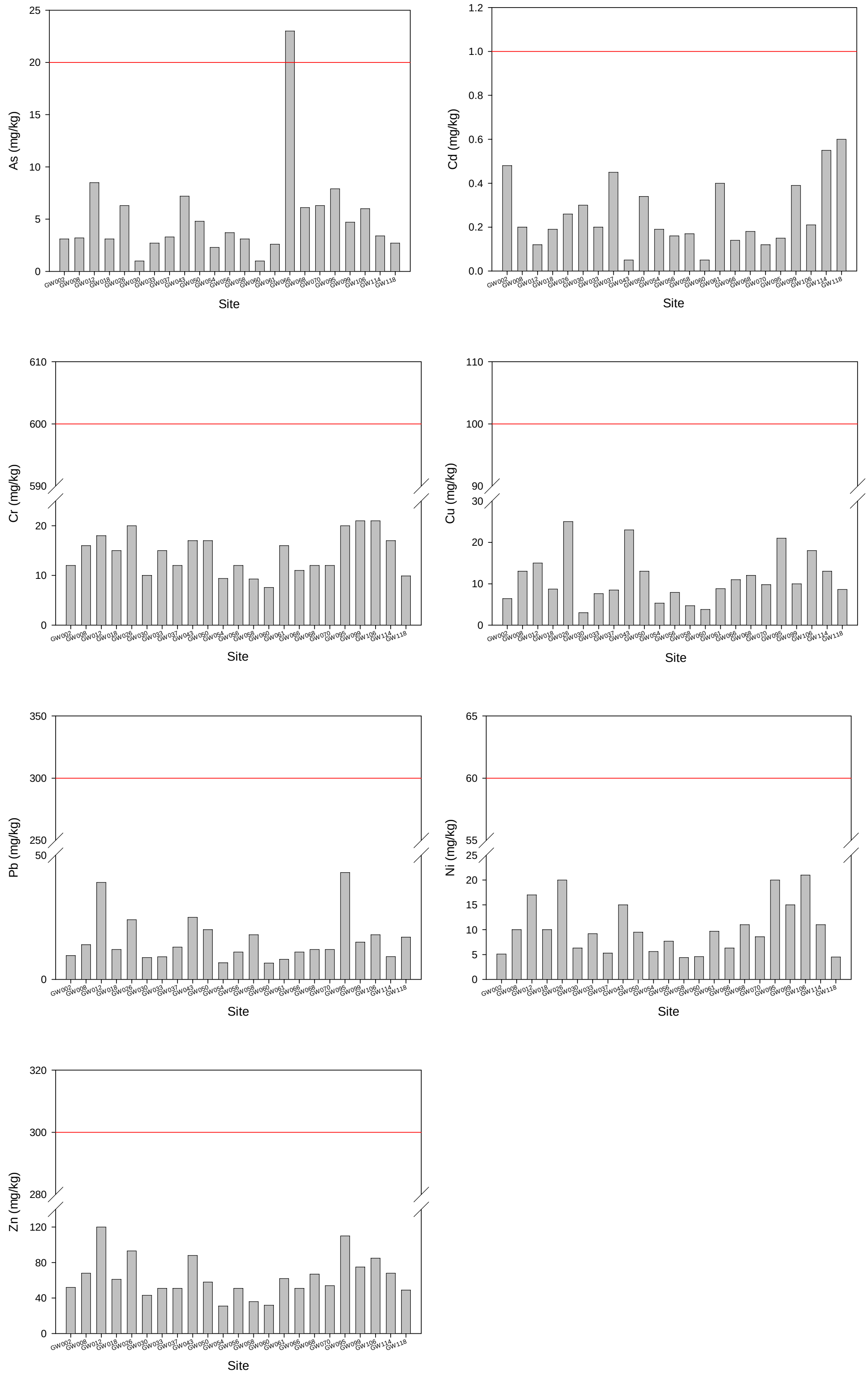

Figure 3.8: Total recoverable heavy metal concentrations at each soil quality monitoring site sampled over 2007/08. The red lines represent the (maximum) guideline values from NZWWA (2003).

3.3 Biological properties

Not all the nitrogen in organic matter can be used by plants; soil organisms change the nitrogen to forms plants can use. Mineralisable nitrogen gives a measure of how much organic nitrogen is available to plants and the activity of the organisms (NLMF 2007). While mineralisable nitrogen is not a direct measure of soil biology, it has been found to correlate reasonably well with microbial biomass carbon, so mineralisable nitrogen can act as a surrogate measure for microbial biomass (SINDI 2008). Of the 23 sites sampled all had optimal mineralisable nitrogen values, except site GW061 which marginally exceeded the upper limit (Figure 3.9).

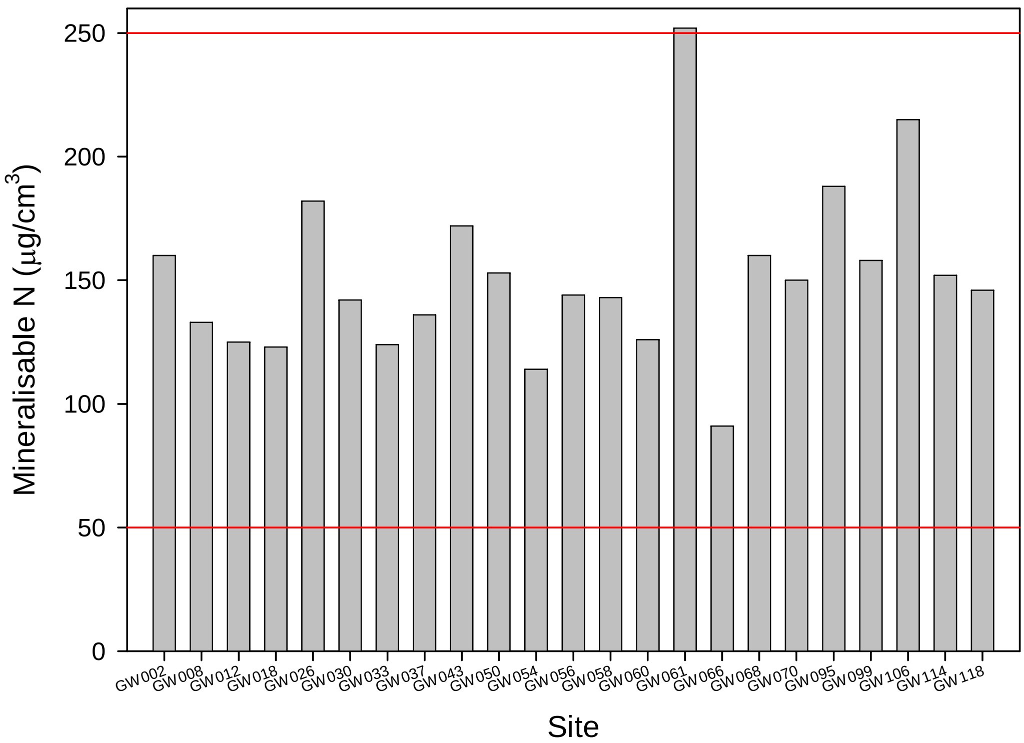

Figure 3.9: Mineralisable nitrogen content at each soil quality monitoring site sampled over 2007/08. The area between the red lines represents the optimal range.

4. Summary

The results of soil quality monitoring for 2007/08 from 23 pastoral drystock farming sites found the health of the soils to generally be in good condition. The primary concerns were compaction and suboptimal nutrient levels (high total N and variable Olsen P) of the soils. While soil compaction by itself may affect farm productivity, excess nitrogen or phosphorus combined with compacted soils can also cause the excess nutrients to leach into groundwater or runoff into surface water bodies and adversely affect water quality. Only two sites (GW095 and GW099) were found to be compacted and have excess nutrients. Soil heavy metal concentrations were all well below recommended guideline values.

5. References

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Acknowledgements

I would like to acknowledge Bryan Stevenson (Landcare Research) for providing the initial interpretation of the results in his report. Also, I would like to thank Tony Faulkner and Jake Brown for helping with the sampling, and the many farmers and landowners for their cooperation and for providing access to their land for sampling.

Appendix 1: Soil quality monitoring sites sampled 2007/08

Site Number	General Location	Easting	Northing	Land use	Soil Type	Soil Order	Date Sampled
GW002	Otaki	2688900	6043836	Drystock	Typic Orthic Brown	Brown Soils	11/04/2008
GW008	Otaki	2690463	6041795	Drystock	Mottled Orthic Brown	Brown Soils	16/04/2008
GW012	Otaki	2690962	6046429	Drystock	Acidic Fluvial Recent	Recent Soils	09/04/2008
GW018	Wairarapa	2729425	6019992	Drystock	Argillic Perch-gley Pallic	Pallic Soils	21/04/2008
GW026	Wairarapa	2732500	6027000	Drystock	Acidic-weathered Fluvial Recent	Recent Soils	02/04/2008
GW030	South Wairarapa	2713333	5990757	Drystock	Mottled Immature Pallic	Pallic Soils	21/04/2008
GW033	South Wairarapa	2700711	5986337	Drystock	Typic Perch-gley Pallic	Pallic Soils	03/04/2008
GW037	Wairarapa	2726881	6025877	Drystock	Typic Argillic Pallic	Pallic Soils	03/04/2008
GW043	Otaki	2692595	6046948	Drystock	Typic Fluvial Recent	Recent Soils	09/04/2008
GW050	Otaki	2693061	6048476	Drystock	Acid Orthic Gley	Gley Soils	09/04/2008
GW054	Porirua	2670159	6012515	Drystock	Typic Orthic Brown	Brown Soils	11/04/2008
GW056	Porirua	2671078	6018154	Drystock	Typic Firm Brown	Brown Soils	11/04/2008
GW058	Porirua	2669434	6011401	Drystock	Mottled Argillic Pallic	Pallic Soils	11/04/2008
GW060	Porirua	2666060	6015735	Drystock	Weathered Orthic Recent	Recent Soils	09/04/2008
GW061	Wairarapa	2739146	6014696	Drystock	Mottled Orthic Brown	Brown Soils	02/04/2008
GW066*****	Wairarapa	2743582	6018712	Drystock	Mottled Argillic Pallic	Pallic Soils	02/04/2008
GW068	Wairarapa	2758329	6029121	Drystock	Weathered Orthic Recent	Recent Soils	02/04/2008
GW070	Wairarapa	2761330	6029062	Drystock	Weathered Orthic Recent	Recent Soils	02/04/2008
GW095	Wairarapa	2733215	6026602	Drystock	Weathered Fluvial Recent	Recent Soils	02/04/2008
GW099	Wairarapa	2738079	6024380	Drystock	Mottled Immature Pallic	Pallic Soils	03/04/2008
GW106	South Wairarapa	2711749	5994670	Drystock	Weathered Orthic Recent	Recent Soils	03/04/2008
GW114	Otaki	2695857	6049924	Drystock	Mottled Immature Pallic	Pallic Soils	09/04/2008
GW118	Otaki	2689900	6043571	Drystock	Typic Orthic Brown	Brown Soils	16/04/2008

* Site was sampled at incorrect location (see p.2 footnote), therefore, results may not be correct for the given land use and soil order.

Appendix 2: Sampling and analytical methods

At each site a 50 m transect is laid out. Following careful excavation, the liner and soil cores are removed as a unit. Soil cores 2.5 cm in diameter to a depth of 10 cm are taken every 2 m along the transect. The 25 individual cores are bulked and mixed in preparation for chemical and biological analyses. Three undisturbed soil samples used for physical analyses are also obtained from each site at 15, 30 and 45 m intervals along the transect by pressing steel liners 10 cm in width and 7.5 cm in depth into the top 10 cm of soil.

Soil analyses were completed at the Landcare Research laboratory in Hamilton (the exception being soil heavy metals analyses which were undertaken at R.J. Hills Laboratory in Hamilton). Where necessary, samples were stored at 5°C until analysis.

Table A2.1: Analytical methods

Indicator	Method
Physical properties	
Dry bulk density	Measured on a sub-sampled core dried at 105°C.
Macroporosity	Determined by drainage on pressure plates at –10 kPa.
Chemical properties	
pH	Measured in water using glass electrodes and a 2.5:1 water-to-soil ratio.
Total C content	Dry combustion method. Using air-dried, finely ground soils using a Leco 2000 CNS analyser.
Total N content	Dry combustion method. Using air-dried, finely ground soils using a Leco 2000 CNS analyser.
Olsen P	Bicarbonate extraction method. Extracting <2 mm air dried soils for 30 mins with 0.5M $NaHCO_3$ at pH 8.5 and measuring the PO_4^{3-} concentration by the molybdenum blue method.
Heavy metals	Total recoverable digestion. Nitric/hydrochloric acid digestion, USEPA 200.2.
Biological properties	
Potential mineralisable N	Waterlogged incubation method. Increase in NH_4^+ concentration was measured after incubation for 7 days at 40°C and extraction in 2M KCl.

Appendix 3: Analytical results

Table A3.1: Analytical results for soil quality monitoring sites sampled in 2007/08

Site No.	pH	Total C mg/cm³	Total N mg/cm³	C:N ratio	Olsen P µg/cm³	NH_4-N µg/cm³	NO_3-N µg/cm³	Mineralisable N µg/cm³	Bulk density Mg/m³	Particle density Mg/m³	Total porosity %v/v	Macro porosity %v/v	Moisture content (@-10kPa) %v/v	Moisture content (@-5kPa) %v/v
GW002	5.3	88.1	**7.6**	11.5	96	77	6.3	160	0.99	2.37	58.4	14.7	43.8	48.3
GW008	6.2	51.4	4.7	10.9	33	66	0.5	133	1.08	2.52	57.3	14.3	43	45.4
GW012	5.8	46.4	3.9	12.0	**11**	19	2.2	125	1.24	2.62	52.7	16.4	36.3	39.2
GW018	5.9	42.6	3.7	11.5	32	21	1.5	123	1.28	2.62	51.3	**8.5**	42.8	45.1
GW026	5.8	51.2	4.8	10.7	74	75	1.7	182	1.23	2.63	53.4	10.9	42.5	44.8
GW030	6.0	43.1	4.1	10.5	43	54	4.9	142	1.24	2.6	52.6	13.7	38.9	41.2
GW033	5.1	50.0	4.7	10.6	53	92	3.3	124	1.29	2.57	49.9	**9.7**	40.2	42.6
GW037	5.8	84.8	6.7	12.6	23	54	4.4	136	0.77	2.4	67.9	25.4	42.5	46.1
GW043	5.7	51.5	5.0	10.4	56	51	0.6	172	1.19	2.6	54.3	**8.1**	46.2	48.7
GW050	6.0	48.8	4.4	11.0	**8**	32	0.7	153	0.97	2.54	61.6	**10**	51.7	55.1
GW054	6.5	50.5	4.3	11.6	**12**	57	0.3	114	0.97	2.51	61.1	17.2	43.9	47.1
GW056	5.6	61.3	5.1	12.1	**9**	21	2.5	144	0.91	2.45	62.7	19	43.8	47.3
GW058	5.3	54.6	4.7	11.7	26	43	5.8	143	1.22	2.53	51.8	12	39.9	41.8
GW060	5.7	40.2	3.6	11.3	22	37	13.9	126	1.13	2.56	56	22	34.1	40.9
GW061	5.2	84.4	**7.8**	10.8	45	105	17.0	**252**	0.98	2.46	60.2	15	45.2	47
GW066*	6.1	41.2	3.8	10.9	**14**	27	0.4	91	1.1	2.57	57.1	16.5	40.6	43.3
GW068	5.9	55.9	5.6	10.0	22	50	0.8	160	1.03	2.5	58.7	14.6	44	45.9
GW070	6.0	43.9	3.6	12.1	36	21	0.4	150	1.25	2.59	51.8	10.1	41.7	43.7
GW095	6.1	62.1	5.8	10.8	**110**	79	2.6	188	1.29	2.61	50.5	**8.6**	41.9	43.7
GW099	**6.9**	58.0	5.8	10.0	**134**	140	0.5	158	1.15	2.56	55.2	**7**	48.2	49.9
GW106	6.1	47.8	5.0	9.6	72	184	0.4	215	1.33	2.63	49.5	**9.1**	40.4	41.8
GW114	6.2	60.9	6.0	10.1	52	77	0.4	152	1.18	2.54	53.6	**4.7**	48.9	51.4
GW118	5.7	85.9	**7.5**	11.5	40	67	1.4	146	0.92	2.39	61.5	18.1	43.4	48

Bold – outside optimal range for the site's specific soil order and land use.

* Site was sampled at incorrect location (see p.2 footnote), therefore, results may not be correct for the given land use and soil order.

Table A3.2: Soil heavy metal concentrations (total recoverable) of soil quality monitoring sites sampled in 2007/08

Site No.	Arsenic (As) mg/kg	Cadmium (Cd) mg/kg	Chromium (Cr) mg/kg	Copper (Cu) mg/kg	Nickel (Ni) mg/kg	Lead (Pb) mg/kg	Zinc (Zn) mg/kg
GW002	3.1	0.48	12	6.4	9.6	5.1	52
GW008	3.2	0.20	16	13	14	10	68
GW012	8.5	0.12	18	15	39	17	120
GW018	3.1	0.19	15	8.7	12	10	61
GW026	6.3	0.26	20	25	24	20	93
GW030	<2.0	0.30	10	3.0	8.8	6.3	43
GW033	2.7	0.20	15	7.6	9.1	9.2	51
GW037	3.3	0.45	12	8.5	13	5.3	51
GW043	7.2	<0.10	17	23	25	15	88
GW050	4.8	0.34	17	13	20	9.5	58
GW054	2.3	0.19	9.4	5.3	6.7	5.6	31
GW056	3.7	0.16	12	7.9	11	7.7	51
GW058	3.1	0.17	9.3	4.7	18	4.4	36
GW060	<2.0	<0.10	7.6	3.8	6.6	4.6	32
GW061	2.6	0.40	16	8.8	8.1	9.7	62
GW066*	23	0.14	11	11	11	6.3	51
GW068	6.1	0.18	12	12	12	11	67
GW070	6.3	0.12	12	9.8	12	8.6	54
GW095	7.9	0.15	20	21	43	20	110
GW099	4.7	0.39	21	10	15	15	75
GW106	6.0	0.21	21	18	18	21	85
GW114	3.4	0.55	17	13	9.2	11	68
GW118	2.7	0.60	9.9	8.6	17	4.5	49

Bold – exceeds recommended guideline value (NZWWA 2003).

* Site was sampled at incorrect location (see p.2 footnote), therefore, results may not be correct for the given land use and soil order.