SOIL QUALITY IN THE MARLBOROUGH REGION IN 2008

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Environmental Science and Monitoring Group

MARLBOROUGH DISTRICT COUNCIL

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Executive Summary

The Marlborough District Council (MDC) has a duty under the Resource Management Act (1991) to monitor the "life supporting capacity of soil" and determine whether current practices will meet the "foreseeable needs of future generations". To help meet these goals the MDC undertakes a soil quality monitoring program that involves collecting soil samples from sites that represent the main land use activities and soil types in the Marlborough region and analysing samples for a suite of soil physical, biological and chemical properties that have been shown to be robust indicators of soil quality.

In this investigation soils were sampled from 19 new soil quality monitoring sites. The sites included five different land use activities including vineyards (5), pasture (5), cropping (4), dairying (4), and exotic forestry (1) representing 11 different soil types from four soil orders.

Monitoring results indicate that 9 out of 19 sites meet all their soil quality targets and four others have one indicator out of the target range. However, monitoring has highlighted that there are some soil quality issues under some land use activities in Marlborough.

All four of the cropping sites sampled showed signs of soil physical deterioration, be it compaction, low macro-porosity or low aggregate stability. Furthermore, three of the four cropping soils also had depleted soil carbon contents and one had an elevated Olsen P value. These results put cropping soils at risk of poor aeration, poor drainage, and structural degradation and will likely result in poor crop performance. In addition the elevated Olsen P coupled with soil compaction increases the possibility of P loss from soil via overflow into waterways.

Two of the dairy pasture sites sampled had elevated anaerobically mineralisable nitrogen concentrations. This potentially poses a risk of nitrogen losses via nitrate leaching from soils into ground and surface water if the volume of irrigation applied is greater than the water-holding capacity of these soils.

Trace element concentrations in Marlborough agricultural soils were generally low and were similar to concentrations found in earlier studies in the Marlborough region and other parts of New Zealand.

It is recommend that to obtain reliable, long-term detection and prediction of trends in soil quality, at least three and preferably five points along a time sequence should be obtained. Therefore repeat monitoring of sites should be conducted in the medium-term (≈ 3 - 5 years) to determine trends over time.

1.0 Introduction

Regional councils (and Unitary Councils) have a responsibility for promoting the management of the natural and physical resources of their region. One of the physical resources that we have a duty under the Resource Management Act (1991) to monitor in the region is the "life supporting capacity of soil" and whether current practices will meet the "foreseeable needs of future generations". The results of soil monitoring provide information that can be used to change or prioritise the way we manage the land environment. Furthermore, trends determined by the monitoring of soils can be used to develop policies and rules that will protect the sustainability of our land resources.

To help determine what effect land use practices are having on the health of soils in the region, in 2000 the Marlborough District Council began a soil quality monitoring program. The monitoring program involved collecting soil samples from a network of sites that represented the main land use activities and soil types within the region and analysing samples for a suite of soil physical, biological and chemical properties that have been shown to be robust indicators of soil quality. It was hoped that periodic monitoring of these sites would provide an early-warning to identify the effects of primary land use on long-term soil quality and also provide an opportunity to track and identify issues relating to the effects of land use on long-term soil quality.

Up until 2007, only 25 soil quality sites had been established and monitored. The results of the monitoring were reported to the Environment Committee early in 2008. However, to provide a more accurate picture of soil quality in the Marlborough region, a larger number of soils need to be sampled from a greater number of sites.

This report will present the results for 19 new soil quality monitoring sites that were sampled and analysed for a suite of soil physical, biological and chemical properties to determine if they meet their target ranges for soil quality.

2.0 Materials and Methods

2.1 Sampling Sites

Soils were sampled from 19 sites that included five different land use activities including vineyards (5), pasture (5), cropping (4), dairy (4), and exotic forest (1) representing 11 different soil types and four soil orders (Table 1).

Table 1 Soil type, soil classification and land use management of sites sampled in Marlborough

Site Code	Soil Type	New Zealand Soil Order	Land use; management
MDC26	Seddon	Pallic	Vineyard; grass in inter-rows
MDC27	Motukarara	Gley	Vineyard; grass in inter-rows
MDC28	Motukarara	Gley	Pasture; beef
MDC29	Warwick	Pallic	Arable; mixed cropping
MDC30	Sedgemere	Pallic	Vineyard; grass in inter-rows
MDC31	Sedgemere	Pallic	Arable; mixed cropping
MDC32	Seddon	Pallic	Arable; mixed cropping
MDC33	Dashwood	Pallic	Arable; mixed cropping
MDC34	Warwick	Pallic	Pasture; sheep
MDC35	Jordan	Pallic	Pasture; sheep
MDC36	Jordan	Pallic	Vineyard; grass in inter-rows
MDC37	Renwick	Brown	Vineyard; grass in inter-rows
MDC38	Renwick	Brown	Pasture; sheep
MDC39	Dashwood	Pallic	Pasture
MDC40	Kaituna	Brown	Pasture; dairying
MDC41	Rai	Recent	Pasture; dairying
MDC42	Pelorus Steepland	Brown	Exotic Forest; *Pinus radiata* forest
MDC43	Pelorus Steepland	Brown	Pasture; dairying
MDC44	Manaroa	Brown	Pasture; dairying

At each site a soil pit was dug to about 1 m depth and a detailed soil profile description was undertaken to confirm the soil type and to note any salient soil features that may affect soil management i.e. rooting depth, mottling, hardpans etc. In addition, details of the site were recorded such as current landuse, present vegetation, slope, elevation, landform, parent material and soil drainage class. This information in presented in Appendix A.

2.2 Soil Sampling

Two types of soil samples were collected from each site. Firstly a composite sample comprising 25 individual cores taken at 2 m intervals along a 50 m transect at a depth of 100 mm. These samples were used for chemical and biological soil analysis. In addition, three undisturbed soil cores (100 mm diameter by 75 mm depth) were sampled at 15-, 30- and 45-m positions along the transect. The soil cores were removed as one unit by excavation around the liner, bagged and loaded into padded crates for transport to the laboratory for analysis. These soil samples were used for physical soil analysis.

In addition, at the four cropping sites, three replicate spade samples were taken at 15-, 30- and 45-m positions along the 50 m transect. This involved cutting a 100 mm by 100 mm by 100 mm undisturbed blocks of soil that were sealed into a polythene bags. These samples were used for measurement of soil aggregate stability.

2.3 Soil Quality Measurements

A number of different soil properties were measured to assess soil quality. Soil chemical characteristics were assessed by soil pH, total carbon, total nitrogen, carbon:nitrogen ratio, Olsen P and trace elements concentration. Soil biological activity was determined by measuring anaerobically mineralisable nitrogen (AMN). Soil physical conditions were assessed using bulk density, particle density and water release characteristics which in turn were used to calculate total soil porosity, air capacity, macroporosity and at cropping sites aggregate stability was also determined (Table 2).

Table 2 Indicators used for soil quality assessment

Indicators	Soil Quality Information	Method
Chemical properties		
Total carbon content	Organic matter status	Dry combustion, CNS analyser
Total nitrogen content	Organic N reserves	Dry combustion, CNS analyser
Soil pH	Acidity or alkalinity	Glass electrode pH meter,
Olsen P	Plant available phosphate	Bicarbonate extraction, molybdenum blue method
Trace elements	Deficiency or toxicity of trace elements in soil	Acid digestion
Biological properties		
Anaerobically mineralisable N	Readily mineralisable nitrogen reserves	Waterlogged incubation at 40 ºC for 7 days
Physical properties		
Dry bulk density	Compaction, volumetric conversions	Soil cores
Particle density	Used to calculate porosity and available water	Specific gravity
Aggregate Stability	Presence of soil crumbs, stable soil structure	Wet sieving the 2 - 4 mm aggregates
Total porosity, air capacity and macroporosity	Soil compaction, aeration, drainage	Pressure plates

2.4 Soil Analyses

2.4.1 Chemical

Total carbon and nitrogen were determined by dry combustion of air-dry soil using a LECO 2000 CNS analyser (Blakemore et al., 1987). Soil pH was measured in water using glass electrodes and a 2.5:1 water to soil ratio (Blackmore et al., 1987). Olsen P was determined by extracting soils for 30 min with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen, 1954) and measuring the phosphate concentration by the molybdenum blue method. Trace element concentrations in soils i.e. total recoverable copper, chromium, cadmium, arsenic, lead, nickel and zinc were determined by digesting soils in nitric/hydrochloric acid and analysing trace elements in the digest by inductively coupled plasma mass spectrometry (US EPA 200.2).

2.4.2 Biological

Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in NH_4-N concentration was measured after incubation for 7 days at 40 ºC and extraction in 2 M KCl (Keeney and Bremner, 1966).

2.4.3 Physical

Dry bulk density was measured on soil samples extruded from cores and dried in an oven at 105°C until the weight remained constant and the sample was then weighed (Gradwell and Birrell, 1979). Macroporosity (-5 kPa), air capacity (-10 kpa) and total porosity were calculated as described by Klute (1986). Particle density was measured by the pipette method. Aggregate stability was measured by wet sieving of the 2 - 4 mm soil fraction. The mean weight diameter (MWD) of aggregates remaining on the 2 mm, 1 mm and 0.5 mm sieve is measured after sieving (Gradwell, 1972).

2.5 Statistics and Data Display

Where appropriate, data were expressed on a weight/volume or volume/volume basis to allow comparison between soils with differing bulk density.

2.6 Targets and Ranges

Target ranges for individual soil characteristics were assessed using 'SINDI'. This is a web-based tool designed by Landcare Research to help interpret the quality of a soil that has been sampled. SINDI allows us to i) compare soil data with information for similar soils stored in the National Soil Database ii) see how our soil measures up against the current understanding of optimal environmental target values and iii) learn about the effect each indicator has on soil quality and some general management practices that could be implemented to improve the soil.

3.0 Results and Discussion

3.1 Comparison of Target Ranges

Figure 1 shows the number of sites not meeting their target ranges for a specific soil type and landuse activity in 2008. Macroporosity was the soil indicator most often not meeting its target range (i.e. 7 sites), followed by bulk density (i.e. 5 sites), Olsen P (i.e. 4 sites) and AMN (i.e. 2 sites). In contrast, soil pH, total C and total N met all of their target ranges. These results are similar to those found for soils sampled in the 2007 soil quality monitoring programme in Marlborough and is what has been found nationally where soil compaction i.e. high bulk density and low macroporosity is recognised as a key soil quality issue.

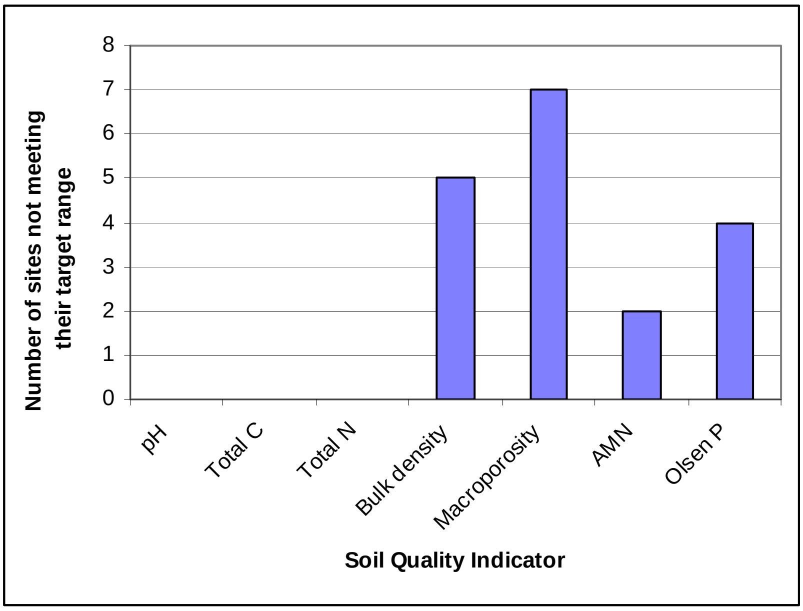

Figure 1 The number of sites not meeting their target range for a specific soil quality indicator.

The results of soil chemical, biological and physical analyses from soils sampled at each site are given in Tables 3 and 4 respectively.

3.2 Soil pH

Soil pH is a measure of the acidity and alkalinity in soil. It is an important soil indicator because it affects nutrient and contaminant availability in plants and the functioning of beneficial soil macro- and micro-organisms. Most plants and soil organisms will have an optimum pH range for growth, and the pH of the soil affects which species will grow best. For example, most forest soils in New Zealand are acidic and indigenous forest species are generally tolerant of acid conditions. In contrast, introduced exotic pasture and crop species require more alkaline conditions.

As indicated in Figure 1, all sites had soil pH values that were within acceptable target ranges for their respective land use. The range of pH values measured from the different land uses are typical of those found elsewhere, with exotic forest soils generally being slightly more acidic than those found under cropping, pastoral and viticulture land uses (Table 3).

Table 3 Chemical and biological characteristic of soils sampled in the Marlborough Region 2008

Site Code	Land use	Soil Type	Soil pH	Olsen P (µg cm^{-3})	Total C (mg cm^{-3})	Total N (mg cm^{-3})	C:N ratio	AMN (µg cm^{-3})
MDC26	Vineyard; inter-rows	Seddon	6.9	32	47.3	4.6	10.3	173
MDC27	Vineyard; inter-rows	Motukarara	6.3	17	43.3	4.5	9.4	135
MDC28	Pasture	Motukarara	5.8	36	57.8	5.0	11.4	122
MDC29	Arable	Warwick	6.2	48	31.0	3.6	8.6	42
MDC30	Vineyard; inter-rows	Sedgemere	6.0	33	32.4	3.7	8.9	49
MDC31	Arable	Sedgemere	6.2	43	29.6	3.4	8.6	41
MDC32	Arable	Seddon	6.3	61	35.4	4.0	8.8	112
MDC33	Arable	Dashwood	5.5	103	52.8	4.6	11.4	84
MDC34	Pasture	Warwick	6.1	36	47.4	4.9	9.7	150
MDC35	Pasture	Jordan	5.4	18	35.0	3.4	10.4	128
MDC36	Vineyard; inter-rows	Jordan	6.8	18	49.4	4.4	11.1	157
MDC37	Vineyard; inter-rows	Renwick	6.9	44	49.8	5.1	9.6	165
MDC38	Pasture	Renwick	6.5	40	49.2	5.0	9.9	106
MDC39	Pasture	Dashwood	6.0	9	52.8	4.9	10.8	156
MDC40	Dairying	Kaituna	6.0	51	48.4	5.3	9.2	299
MDC41	Dairying	Rai	6.1	24	60.7	5.7	10.6	327
MDC42	Exotic Forest	Pelorus Steepland	5.1	6	56.2	2.9	19.3	60
MDC43	Dairying	Pelorus Steepland	5.2	9	53.5	4.5	11.8	141
MDC44	Dairying	Manaroa	6.2	11	41.2	4.2	9.7	204

3.3 Total Soil Carbon

Total carbon is the total amount of carbon in soil which includes carbonates and soil organic matter carbon. Typically New Zealand soils contain only small amounts of carbonate; hence total carbon is generally considered a good measure of organic matter carbon in soil. Organic matter is important for soil quality because it helps soil retain moisture and nutrients, it contributes to a stable soil structure and it provides a source of energy for soil microbes.

All sites had total carbon contents within acceptable target ranges for their respective land use activity (Figure 1). However, at three of the four cropping sites i.e. MDC29, MDC31 and MDC32 soil carbon contents were at the lower boundary of their target range (Table 3). These results put these cropping soils at risk of poor aeration, poor drainage and soil structural degradation (see section 3.10). It would be desirable if cultural practices are adopted such as introducing a pasture phase in the rotation or minimal tillage which should help increase the amount of soil organic matter (carbon) in these soils.

3.4 Total Soil Nitrogen

Nitrogen is an essential major nutrient for plants and animals, and the store of organic matter nitrogen is an important measure of soil fertility. Typically in topsoils, organic matter nitrogen comprises more than 90% of the total nitrogen. However organic matter nitrogen needs to be mineralised to inorganic forms (i.e. ammonium and nitrate) by soil microbes before it can be utilised by plants.

Like for total carbon, all sites had total nitrogen contents within acceptable target ranges for their respective land use activity (Figure 1). However, as was found for total carbon, three of the four cropping sites i.e. MDC29, MDC31 and MDC32 also had the lowest total nitrogen values (Table 3).

3.5 Carbon:Nitrogen Ratio

The balance of the amount of carbon:nitrogen in soil is called the carbon-nitrogen ratio (C:N). This ratio is important as a guide to the state of decomposition or likely ease of decomposition and mineralization of nutrients from organic residues in soils and is a measure of organic matter quality.

All sites had acceptable C:N ratios apart from the exotic forestry site i.e. MDC43 where the ratio of 19:3 is considered slightly below the optimal ratio of 15:1 for a forestry soil from a productive point of view (Table 3). However, this ratio this could be relatively easily be altered by the application of a nitrogen fertiliser.

3.6 Olsen P

Phosphorus is an essential nutrient for both plants and animals. Only a small amount of the total phosphorus in soil is in forms able to be taken up by plants (plant-available P). The Olsen P method is a chemical extractant that provides a reasonable estimate of the amount of plant-available phosphorus by measuring phosphate from soil solution and exchange surfaces. A high Olsen P value in soil may result in phosphorus losses from soil which potentially can have a negative impact on water quality.

Olsen P concentrations varied 17-fold between sites with the lowest value found at the exotic forestry site and highest value at one of the cropping sites i.e. MDC33 (Table 3). As indicated in Figure 1, four sites had Olsen P values out of the desired target range. At site MDC33, a cropping site, the Olsen P value was higher than the desired target range. This reflects the regular application of phosphate fertiliser to soil to stimulate plant growth at this site which is a necessary farming practice. An Olsen P concentration above the target range can lead to water quality issues such as eutrophication if this phosphorous is lost from soil by leaching or more likely by overland flow. In contrast, at three other sites i.e. MDC39, MDC43 and MDC44 Olsen P concentrations were below their target range. Phosphorous concentrations in soils can be increased relatively easily by the application of phosphate fertilisers to soil, hence these low values are not of any major concern.

3.7 Anaerobically Mineralisable Nitrogen

Anaerobically mineralisable nitrogen is a measure of the amount of nitrogen that can be supplied to plants through the decomposition of soil organic matter by soil microbes. It is a useful measure of the soil organic matter quality in terms of its ability to store nitrogen. However, the amount of AMN has also been found to correspond with the amount of soil microbial biomass – hence it is also a useful indictor of microbial activity in soils.

With the exception of two of the dairy sites i.e. MDC40 and MDC41 which had excessive AMN concentrations, all values were within the target range for their respective land use activity. An AMN values above the target range is regarded as important as it can potentially lead to water quality issues if nitrogen is lost from soil as nitrate, primarily by leaching.

3.8 Bulk Density

Bulk density is the weight of soil in a specified volume and provides a measure of how loose or compacted a soil is. Loose soils may be subject to increased risk of erosion, dry out quickly, and plant roots find it difficult to get purchase and absorb water and nutrients. In contrast, compacted soils have poor aeration and are slow draining. The consequences of compacted soil may include reduced supply of air to plant roots, increased resistance to penetration that may limit root extension and germination, and reduced capacity of the soil to store water that is available to plants. Further, reduced water entry into the soil may increase water runoff over the soil surface.

Table 4 Physical characteristic of soils sampled in the Marlborough Region 2008

Site Code	Land use	Soil Type	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Total porosity (% v/v)	Macro-porosity (%v/v)	Air-filled porosity (%v/v)	Aggregate Stability (mwd)
MDC26	Vineyard; inter-rows	Seddon	1.25	2.63	53	13	18	
MDC27	Vineyard; inter-rows	Motukarara	1.08	2.61	59	20	22	
MDC28	Pasture	Motukarara	0.96	2.58	63	19	21	
MDC29	Arable	Warwick	1.35	2.62	48	11	14	0.61
MDC30	Vineyard; inter-rows	Sedgemere	1.41	2.62	46	5	9	
MDC31	Arable	Sedgemere	1.23	2.62	53	17	20	0.45
MDC32	Arable	Seddon	1.41	2.63	46	6	8	1.16
MDC33	Arable	Dashwood	1.35	2.58	48	5	5	1.56
MDC34	Pasture	Warwick	1.25	2.58	52	12	15	
MDC35	Pasture	Jordan	1.09	2.57	57	10	13	
MDC36	Vineyard; inter-rows	Jordan	1.45	2.59	44	1	2	
MDC37	Vineyard; inter-rows	Renwick	1.28	2.59	51	10	11	
MDC38	Pasture	Renwick	1.20	2.58	54	13	14	
MDC39	Pasture	Dashwood	1.23	2.57	52	10	12	
MDC40	Dairying	Kaituna	1.03	2.53	60	2	3	
MDC41	Dairying	Rai	0.95	2.49	63	4	5	
MDC42	Exotic Forest	Pelorus Steepland	1.00	2.65	62	17	19	
MDC43	Dairying	Pelorus Steepland	0.84	2.52	67	10	13	
MDC44	Dairying	Manaroa	1.08	2.64	60	1	2	

Five sites had bulk density values that were higher than their respective target ranges (Figure 1). These include three of the four cropping sites and the inter-rows of two vineyard sites (Table 4). The high bulk density values at the cropping sites are likely related to the relatively low organic matter i.e. total carbon contents in these cropping soils which were all at the lower boundary of their target range. It is well recognised that organic matter is an integral component of stable structure in soils. Furthermore, the tracking of heavy machinery in cropping operations is also likely to have contributed to elevated bulk density. Plate 1 shows the surface crusting and poor soil structure of the topsoil at one of the cropping sites sampled.

Plate 1 Compacted topsoil at one of the cropping sites sampled. Note the surface crust which reduces water infiltration, can increase surface run-off and reduce seed germination.

The high bulk density values found in the inter-row at two of the vineyard sites is likely related to vehicle traffic in this zone which is subject to machinery movement to undertake activities such as mowing, spraying, harvesting and pruning.

3.9 Macroporosity

Macroporosity is a measure of the proportion of large pores in the soil. Macropores are important for penetration of air into soil, extension of roots down into the soil and drainage of water. Typically macropores and are the first to be lost when the soil is compacted.

Seven sites did not meet their target for macroporosity (Figure 1). These included three of the dairy sites sampled i.e. MDC 40, MDC41 and MDC44, two of the cropping sites i.e. MDC32 and MDC33 and two vineyard sites i.e. MDC30 and MDC36 (Table 4).

The low macroporosity values on the dairy sites are likely related to heavy grazing or grazing under wet conditions where animal treading can lead to pugging of soil (Plate 2). At one site i.e. MDC44, which had a macro-pore value of 1 %, there was evidence of compaction mottles in the topsoil (Appendix A). Research has shown that macroporosity values below a 10% threshold has been shown to adversely affect pasture production. Furthermore, low macroporosity may result in poor water infiltration which may increase overland flow and the potential for nutrient losses such as phosphorous from soils.

Interestingly, low macroporosity values are typically associated with high bulk density values. While this was the case with the cropping sites, this was not observed at the three dairy sites which had low macroporosity but bulk density values were within their target ranges. One possible explanation is that compaction has reduced the volume of macropores at the dairy sites, but the adequate total organic carbon at these sites is sufficient to help the soil resist overall compaction. The net result is presumably a change in the pore-size distribution, with a decrease in the macropore volume and an increase in the volume of the smaller pore sizes.

Plate 2 Example of soil recovering after pugging at one the dairy sites sampled.

At the cropping sites, the low macroporosity values are likely related to the depleted organic matter in these soils and the use of heavy machinery. While the low macroporosity values at the two vineyard sites is likely related to machinery movement to undertake activities such as mowing, spraying, harvesting and pruning.

3.10 Aggregate Stability

Aggregate stability refers to the ability of soil aggregates to resist disruption when forces such as rapid wetting and mechanical abrasion are applied. In general a soil with adequate amounts of soil organic matter will have stable soil aggregates and therefore a higher aggregate stability. A stable soil structure is important to allow water and air movement in soils and to minimise surface erosion.

Aggregate stability measurements were made at all of the cropping sites with values ranging from 0.45 to 1.56 MWD (Table 4). Although there are no specific target ranges currently available for aggregate stability, generally any value below about 1.5 MWD is considered on the low side and likely to have a negative effect on crop production (Francis *et al.*, 1991). The low aggregate stability values in the cropping soils are likely again linked to the related to the relatively low organic matter i.e. total carbon contents in these soils which were for three soils at the lower boundary of their target range. Furthermore, all of the cropping sites are on Pallic soils which typically have high slaking potential (Hewitt, 1993) and are usually regarded as unsuitable for continuous cropping to due to their potential for soil structural collapse.

3.11 Trace Elements

Trace elements can accumulate in soils from a range of different sources. At elevated concentrations these have the potential to have an adverse effect on soil and plant fertility, animal health and in some cases accumulate in the human food chain. It is therefore important we have information on the concentrations of key trace element in soils.

Table 5 summarises trace element concentrations in soils from the 21 sites. On average concentrations were 4 µg cm^{-3} for arsenic, 0.22 µg cm^{-3} for cadmium, 26 µg cm^{-3} for chromium, 16 µg cm^{-3} for copper, 17 µg cm^{-3} for nickel, 14 µg cm^{-3} for lead and 83 µg cm^{-3} for zinc. These concentrations are low and are almost the same as the concentrations found in 25 soil quality monitoring sites sampled in Marlborough in 2007. Furthermore, concentrations are similar to typical background concentrations found in New Zealand soils.

With the exception of cadmium, there didn’t appear to be any difference in trace element concentrations between land use activities. For cadmium it was found that there were higher concentrations on dairy sites; most likely related to higher inputs of phosphate fertiliser which has been shown to contain cadmium as an incidental impurity. However cadmium concentrations are still significantly lower than current environmental guideline values.

Table 5 Trace element concentrations in soils sampled in the Marlborough Region 2008

Site Code	Land use	Soil Type	As (µg/cm3)	Cd (µg/cm3)	Cr (µg/cm3)	Cu (µg/cm3)	Ni (µg/cm3)	Pb (µg/cm3)	Zn (µg/cm3)
MDC26	Vineyard; inter-rows	Seddon	3.7	0.12	27	17	21	12	93
MDC27	Vineyard; inter-rows	Motukarara	5.4	0.11	25	19	29	21	80
MDC28	Pasture	Motukarara	4.8	0.10	19	15	23	16	67
MDC29	Arable	Warwick	3.4	0.36	24	15	18	15	117
MDC30	Vineyard; inter-rows	Sedgemere	5.6	0.18	37	17	24	17	116
MDC31	Arable	Sedgemere	4.7	0.21	31	15	21	15	101
MDC32	Arable	Seddon	5.8	0.28	41	23	33	18	137
MDC33	Arable	Dashwood	3.7	0.22	30	12	16	15	103
MDC34	Pasture	Warwick	3.0	0.19	16	11	14	14	105
MDC35	Pasture	Jordan	3.0	0.12	12	5	7	11	46
MDC36	Vineyard; inter-rows	Jordan	4.2	0.15	16	17	10	14	63
MDC37	Vineyard; inter-rows	Renwick	4.0	0.22	22	15	15	17	96
MDC38	Pasture	Renwick	3.7	0.24	20	10	16	16	86
MDC39	Pasture	Dashwood	3.4	0.12	22	10	13	11	70
MDC40	Dairying	Kaituna	4.1	0.44	18	15	10	13	65
MDC41	Dairying	Rai	6.9	0.56	64	20	27	12	61
MDC42	Exotic Forest	Pelorus Steepland	5.2	0.10	29	22	11	12	50
MDC43	Dairying	Pelorus Steepland	4.3	0.22	23	18	11	10	64
MDC44	Dairying	Manaroa	5.3	0.27	17	18	13	11	61

4.0 Summary

Monitoring results indicate that 9 out of 19 sites meet all their soil quality targets and four others have one indicator out of the target range. However, monitoring has highlighted that there are some soil quality issues under some land use activities in Marlborough.

- All four of the cropping sites sampled showed signs of physical deterioration be it soil compaction, low macro-porosity or low aggregate stability. Furthermore, three of the four cropping soils also had soil carbon contents at the lower end of their target range and one site had an elevated Olsen P value. These results put cropping soils at risk of poor aeration, poor drainage, and structural degradation and will likely result in reduced crop growth. It is possible that this was due to intensive cultivation and/or insufficient pasture rotations within the mixed cropping rotation. In addition the elevated Olsen P coupled with soil compaction increases the possibility of P loss from this soil via overflow into waterways during large rainfall events.
- Two of the dairy pasture sites sampled had elevated anaerobically mineralisable nitrogen concentrations. This potentially poses a risk of nitrogen losses via nitrate leaching from soils into ground and surface water if the volume of irrigation applied is greater than the water-holding capacity of these soils.
- Trace element concentrations in Marlborough agricultural soils were generally low and were similar to concentrations found in other parts of New Zealand. However there should be long-term monitoring of cadmium on dairy farm sites to determine changes over time.
- It is recommended that repeat monitoring of these at-risk sites be conducted in the medium-term (≈ 5 years) to determine the rate of change over time.
- It is also recommended that the number of sites currently being monitored should be expanded to include sites on soil types that are not currently part of the monitoring programme.

5.0 References

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APPENDIX A

Sample name: MDC 26
Soil Name: Seddon
Location: near Old Ford Road, Awatere Valley
GPS Coordinates: E2594569 N5946915
Land use: Vineyard
Topography: late glacial aggradational terrace surface
Elevation: 118 m
Slope: 0°
Soil material: loess
Soil drainage: moderately well drained
Date sampled: 21/09/07

Horizon	Depth (cm)	Soil description
A	0 - 25	dark brown (10YR 3/3) silt loam; weakly developed medium polyhedral structure; weak soil strength; friable; many fine and few coarse roots
AB	25 - 30	dark brown (10YR 3/3) and olive brown (2.5Y 4/4) silt loam; moderately developed medium polyhedral and blocky structure; weak to slightly firm soil strength; friable; many fine and very few coarse roots
Bw	30 - 80	olive brown (2.5Y 4/4) heavy silt loam; weakly developed coarse blocky structure; slightly firm soil strength; brittle; few fine roots
Bw(g)	80+	dark yellowish brown (10YR 4/4) silt loam; 10% pinkish grey (5YR 6/2) and 5% yellowish red (5YR 4/8) fine faint mottles; weakly developed very coarse prismatic structure; weak soil strength; brittle;

Sample name: MDC 27
Soil name: Motukarara
Location: Cnr of Dillons Point and Eckford Road
GPS Coordinates: E2595546 N5965130
Land use: Vineyard
Topography: estuarine sediments
Elevation: 2 m
Slope: 0°
Soil material: saline alluvium
Soil drainage: imperfectly
Date sampled: 08/10/07

Horizon	Depth (cm)	Soil description
A	0 - 18	dark greyish brown (10YR 4/2) silt loam; moderately developed fine to medium polyhedral structure; firm soil strength; brittle; common fine and coarse roots; indistinct boundary
Bw	18 -30	Pale brown grey (2.5YR 6/2) silty clay loam; weakly to moderately developed fine polyhedral structure; slightly firm soil strength; few coarse roots; indistinct boundary;
Bw(g)	30 - 40	Very dark grey (5Y 4/1) silty clay loam; weakly developed fine polyhedral structure; fine distinct mottles; weak soil strength; friable;
Cg	40+	Very dark grey (5Y 4/1) to grey (5Y 5/1) sandy loam to sand; apedal; massive; weak soil strength; many coarse mottles;

Sample name: MDC 28
Soil name: Motukarara
Location: Cnr of Dillons Point and Eckford Road
GPS Coordinates: E2595663 N5965072
Land use: Dryland pasture
Topography:
Elevation: 4 m
Slope: 0°
Soil material: saline alluvium
Soil drainage: imperfectly
Date sampled: 08/10/08

Horizon	Depth (cm)	Soil description
A	0 - 20	Dark greyish brown (10YR 4/2) silt loam; moderately developed fine polyhedral structure; weak to slightly firm soil strength; friable; common fine and coarse roots; indistinct boundary
Bw	20 - 45	Pale brown grey (2.5YR 6/2) heavy silt loam; weakly to moderately developed fine polyhedral structure; slightly firm soil strength; firm; few coarse roots; indistinct boundary
Bw(g)	45 - 62	Very dark grey (5Y 4/1) silty clay loam; weakly developed fine polyhedral structure; few fine distinct mottles; slightly firm soil strength; friable; few coarse roots; indistinct boundary
Cg	62+	Very dark grey (5Y 4/1) to grey (5Y 5/1) sandy loam to sand; apedal; massive; weak soil strength; many coarse mottles; very few coarse roots

Sample site: MDC 29
Soil Name: Warwick
Location: Marama Road, Awatere Valley
GPS Coordinates: E2593300 N5944639
Land use: Process food cropping - peas
Topography: older terrace surface
Elevation: 155 m
Slope: 0°
Soil material: postglacial fluvial outwash sheet
Soil drainage: moderately well drained
Date sampled: 20/10/08

Horizon	Depth (cm)	Soil description
A	0 - 20	dark brown (10YR 3/3) silt loam; 7% coarse un-weathered stones; massive to cloddy; dense; prismatic structure; firm soil strength; few fine roots
AB	20 - 29	dark yellowish brown (10YR 5/4) and dark brown (10YR 3/3) silt loam; 5% coarse un-weathered stones; weakly developed medium blocky structure; slightly firm soil strength; brittle; few fine roots
Bw1	29 - 45	dark yellowish brown (10YR 5/4) silt loam; 5% medium un-weathered stones; moderately developed blocky and polyhedral structure; slightly firm soil strength; brittle; very few fine roots
Bw2	45 - 60	dark yellowish brown (10YR 4/4) heavy silt loam; 10% fine and medium stones; 10% strong brown (7.5YR 5/8) fine distinct mottles; moderately developed blocky structure; weak soil strength; brittle
BC	60 - 70+	light olive brown (2.5Y 5/4) sandy clay loam; 5% strong brown (7.5YR 5/8) fine distinct mottles; weakly developed blocky structure; weak soil strength; brittle

Sample name: MDC 30
Soil Name: Sedgemere
Location: Marama Road, Awatere Valley
GPS Coordinates: E2594864 N5945713
Land use: Vineyard
Topography: older terrace surface
Elevation: 140 m
Slope: 0°
Soil material: older loess
Soil drainage: imperfectly drained
Date 20/10/08

Horizon	Depth (cm)	Soil description
A	0 - 19	very dark grayish brown (10YR 3/2) silt loam; weakly developed coarse blocky and medium polyhedral structure; weak soil strength; friable; many fine roots
AB	19 - 28	light olive brown (2.5Y 5/4) and very dark grayish brown (10YR 3/2) silt loam; weakly developed coarse blocky and polyhedral structure; weak soil strength; friable; few fine roots
Bw1	28 - 43	light olive brown (2.5Y 5/4) heavy silt loam; weakly developed coarse blocky and polyhedral structure; firm soil strength; brittle; very few fine roots
Bw2	43 - 55	yellowish brown (10YR 5/4) heavy silt loam; 5% yellowish brown (10YR 5/8) and 40% olive (5Y 5/3 and 5Y 5/3) fine distinct mottles; weakly developed coarse blocky structure; weak soil strength; brittle; very few fine roots
Bw(g)1	55- 65	olive (5Y 5/3) clay loam; 10% yellowish brown (10YR 5/8) fine distinct mottles; weakly developed coarse blocky structure; semi deformable; very few fine roots
Bw(g)2	65 - 85	olive to light olive grey (5Y 5/3-6/2) clay loam; 40% dark yellowish brown (10Y 4/6) and 15% brown (10YR 4/3) medium distinct mottles; weakly developed coarse to very coarse blocky structure; weak soil strength; friable; very few fine roots
Bg	85 - 95	light yellowish brown (2.5Y 6/4) heavy silt loam; 30% dark yellowish brown (10YR 4/6) medium distinct mottles; weakly developed blocky coarse structure; friable
BCx	95+	yellowish brown (10YR 5/6) silt loam; strongly developed coarse prismatic structure; very firm soil strength

Sample name: MDC 31
Soil Name: Sedgemere
Location: Marama Road, Awatere Valley
GPS Coordinates: E2594392 N5945426
Land use: Process food crop - Spinach
Topography: Older terrace surface
Elevation: 143 m
Slope: 2°
Soil material: Older loess
Soil drainage: Moderately well drained
Notes: the site is near the upper edge of a shallow depression and may be better drained than elsewhere
Date 20/10/08

Horizon	Depth (cm)	Soil description
A	0 - 18	dark brown (10YR 3/3) silt loam; weakly developed medium blocky and polyhedral structure; slightly firm soil strength; brittle; many fine roots,
AB	18 - 27	dark brown (10YR 3/3) and light olive brown (2.5Y5/4) silt loam; weakly developed coarse blocky structure; slightly firm soil strength; few fine roots,
Bw1	27 - 36	light olive brown to yellowish brown (2.5Y 5/4-10YR 5/6) heavy silt loam; moderately developed coarse blocky structure; firm soil strength; brittle; very few fine roots
Bw2	36 - 54	light olive brown (2.5Y 5/4) heavy silt loam; 7% brownish yellow (10YR 6/6) fine distinct mottles; moderately developed coarse blocky structure; firm soil strength; brittle
Bw3	54 - 75	olive to light olive brown (5Y 5/4-2.5Y 5/4) silt loam; 5% olive (5Y 4/8) fine distinct mottles; moderately developed coarse blocky structure; slightly firm soil strength; brittle
Bw4	75 - 94	light yellowish brown (2.5Y 6/4) silt to silt loam; 15% dark yellowish brown (10YR 4/4) coarse prominent mottles; moderately developed coarse blocky structure; slightly firm soil strength; brittle
BCx	94 - 100+	BCx 94-100+ yellowish brown (10YR 5/6) silt loam; olive (5Y 5/8) clay/organic thin accumulation at the top of the horizon; strongly developed coarse prismatic structure; hard soil strength

Sample name: MDC 32
Soil Name: Seddon
Location: near Old Ford Road, Awatere Valley
GPS Coordinates: E2594213 N5946863
Land use: Lucerne
Topography: Late glacial aggradational terrace surface
Elevation: 126 m
Slope: 0°
Soil material: Loess
Soil drainage: Moderately well drained
Date 21/10/08

Horizon	Depth (cm)	Soil description
A	0 - 21	dark brown (10YR 3/3) silt loam; weakly developed medium polyhedral structure; weak soil strength; friable; many fine and few coarse roots
AB	21 - 30	dark brown (10YR 3/3) and olive brown (2.5Y 4/4) silt loam; moderately developed medium polyhedral and blocky structure; weak to slightly firm soil strength; friable; many fine and very few coarse roots
Bw1	30 - 52	olive brown (2.5Y 4/4) heavy silt loam; weakly developed coarse blocky structure; slightly firm soil strength; brittle; few fine roots,
Bw2	52 - 70	olive brown (2.5Y 4/4) silt loam; 5% dark yellowish brown (10YR 4/6) very fine distinct mottles; weakly developed coarse blocky structure; brittle; weak soil strength; few fine roots
Bw3(g)	70 – 95+	dark yellowish brown (10YR 4/4) silt loam; 10% pinkish grey (5YR 6/2) and 5% yellowish red (5YR 4/8) fine faint mottles; weakly developed very coarse prismatic structure; weak soil strength; brittle; very few fine roots

Sample name: MDC 33
Soil name: Dashwood
Location: Seaview
GPS Coordinates: E2606005 N5952705
Land use: Process food cropping - peas
Topography: Late glacial aggradational terrace
Elevation: 21 m
Slope: 0°
Soil material: Thin loess? over gravelly alluvium
Soil drainage: Well drained
Date 21/10/08

Horizon	Depth (cm)	Soil description
A	0 - 17	dark brown (10YR 3/3) silt loam; 2% medium to very coarse stones; moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots,
AB	17 - 30	dark yellowish brown and brown to dark brown (10YR 4/4+ 10YR 4/3) silt loam; 2% medium to very coarse stones; moderately developed polyhedral and blocky structure; weak soil strength; friable; few fine roots
Bw1	30 - 43	dark yellowish brown (10YR 4/6) silt loam; 4% medium and very coarse stones; moderately developed medium blocky structure; weak soil strength; brittle; few fine roots
Bw2	43 - 60	brown to dark brown (10YR 4/4) sandy silt loam; 60% medium to coarse stones; weakly developed fine polyhedral structure; friable; few roots
BC	60 -75+	light olive brown (2.5Y 5/4) sandy gravel; 75% medium to very coarse stones; loose; single grain structure; very few roots

Sample name: MDC 34
Soil name: Warwick
Location: Burtergill
GPS Coordinates: E2597927 N5951337
Land use: Grazing, lucerne
Topography: Late glacial aggradational terrace
Elevation: 98 m
Slope: 0°
Soil material: Postglacial sheet outwash
Soil drainage: Well drained
Date 21/10/08

Horizon	Depth (cm)	Soil description
A	0 - 18	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; weak soil strength; friable; many fine and coarse roots
AB	18 - 31	dark brown and dark yellowish brown (10YR 3/3 + 4/6) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; weak soil strength; friable; few fine and coarse roots
Bw	31 - 46	light yellowish brown (10YR 6/4) heavy silt loam to clay loam; 10% dark yellowish brown (10YR 4/4) fine distinct mottles; weakly developed medium blocky structure; 2% fine to coarse stones; weak soil strength; brittle; few fine and coarse roots
Bw2	46 - 64	pale olive (2.5Y 6/4) heavy silt loam; 10% dark yellowish brown (10YR 4/4) fine distinct mottles; weakly developed medium blocky structure; 5% fine stones; slightly firm soil strength; brittle; few fine roots
BC	64 -75+	olive 2.5Y 5/4) silt loam to heavy silt loam; 15% yellowish red (5YR 5/8) medium distinct mottles; weakly developed coarse to very coarse blocky structure; firm soil strength; brittle; few fine roots

Sample name: MDC 35
Soil name: Jordan
Location: Waihopai Valley Road
GPS Coordinates: E2574008 N5960776
Land use: Grazing, dryland pasture
Topography: Slightly undulating older terrace
Elevation: 107 m
Slope: 0°
Soil material: Older loess
Soil drainage: Imperfectly
Date 22/10/08

Horizon	Depth (cm)	Soil description
A	0 - 20	brown (10YR 5/3) silt loam; moderately developed medium polyhedral structure; weak soil strength; friable; many fine and few coarse roots,
AB	20 – 27	brown (10YR 5/3) and pale yellow (2.5Y 7/4) silt to silt loam; moderately developed medium polyhedral structure; weak soil strength; friable; many fine roots,
E	27 – 41	pale yellow (2.5Y 7/4) heavy silt loam; 20% yellowish brown fine distinct mottles; weakly developed medium polyhedral and coarse blocky structure; weak soil strength; friable few fine roots
Bg1	41 – 55	pale olive (5Y 6/3) clay loam; 40% yellowish red (5Y 4/6) fine distinct mottles; moderately to strongly developed coarse blocky structure; firm soil strength; semi deformable; grey (5YR 5/1) clay/organic coatings along ped faces; very few fine roots
Bg2	55 - 75	dark yellowish brown (10YR 4/4) clay loam; 40% grey (5YR 5/1) medium distinct mottles, mostly in veins; strongly developed coarse blocky structure; firm soil strength; semi-deformable; very few fine roots
Bx	75 – 80 +	dark yellowish brown (10YR 4/4) silt loam; 10% grey (5YR 5/1) medium distinct mottles, mostly in veins; strongly developed coarse to very coarse prismatic structure; hard soil strength

Sample name: MDC 36
Soil name: Jordan
Location: Waihopai Valley Road
GPS Coordinates: E2574199 N5960540
Land use: Vineyard
Topography: Slightly undulating older terrace
Elevation: 115m
Slope: 0°
Soil material: Older loess
Soil drainage: Imperfect
Date 22/10/08

Horizon	Depth (cm)	Soil description
A	0 - 17	dark greyish brown (10YR 4/2) silt loam; moderately developed medium polyhedral structure; weak soil strength; many fine and few coarse roots
AB	17 - 26	dark greyish brown and pale yellow (10YR 4/2 + 2.5Y 7/4) silt to silt loam; moderately developed medium polyhedral structure; weak soil strength; many fine roots
E	26 - 36	pale yellow (2.5Y 7/4) silt loam to heavy silt loam;15% brownish yellow (10YR 6/8) fine distinct mottles; weakly developed coarse blocky structure; weak soil strength; brittle; few fine roots
Bwg1	36 - 57	yellowish brown (10YR 5/8) clay loam; 60% strong brown (7.5YR 5/8) and 20% light yellowish brown (2.5Y 6/4) medium distinct mottles; strongly developed coarse blocky, breaking to polyhedral, structure; firm; semi-deformable; few fine roots; distinct grey (5YR 5/1) clay/organic coatings
Bwg2	57 - 85	brownish yellow (10YR 5/6) clay loam; 15% light yellowish brown (2.5Y 6/4) medium distinct mottles, mostly in veins; strongly developed coarse prismatic and blocky structure; firm; semi-deformable; very few fine roots; distinct grey (5YR 5/1) clay/organic coatings
Bx	85+	brownish yellow (10YR 5/6) silt loam; 10% light yellowish brown (2.5Y 6/4) medium distinct mottles; strongly developed very coarse prismatic structure; hard soil strength; distinct grey (5YR 5/1) clay/organic coatings

Sample name: MDC 37
Soil name: Renwick
Location: Waihopai Valley Road
GPS Coordinates: E2575012 N5961944
Land use: Vineyard
Topography: Slightly undulating terrace
Elevation: 102 m
Slope: 1°
Soil material: Post-glacial sheet outwash
Soil drainage: Well drained
Date 23/10/08

Horizon	Depth (cm)	Soil description
A	0 - 16	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; 15% coarse stones; weak soil strength; very friable; very few fine roots
AB	16 - 23	dark brown (10YR 3/3) and dark yellowish brown (10YR 3/4) silt loam; moderately developed fine polyhedral structure; 25% coarse stones; weak soil strength; friable; very few fine roots
Bw	23 - 36	dark yellowish brown (10YR 3/4) gravelly silt loam; weakly developed fine polyhedral structure; 65% fine to very coarse stones; very friable; very fine roots
BC	36 - 45	dark yellowish brown (10YR 3/6) gravel; apedal; 70% fine to boulder sized stones; loose; very few fine roots
C	45 – 65+	olive brown to dark yellowish brown (2.5Y 4/4-10YR 4/4) gravel; apedal; 70% coarse to very coarse stones; loose

Sample name: MDC 38
Soil name: Renwick
Location: Waihopai Valley Road
GPS Coordinates: E2575033 N5961989
Land use: Dryland pasture
Topography: Slightly undulating terrace
Elevation: 100 m
Slope: 1°
Soil material: Post-glacial sheet outwash
Soil drainage: Well drained
Date 23/10/08

Horizon	Depth (cm)	Soil description
A	0 - 18	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; weak soil strength; friable; many fine roots
AB	18 - 27	dark brown and dark yellowish brown to olive brown (10YR 3/3 and 10YR 4/4-2.5Y 4/4) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; weak soil strength; friable; many fine roots
Bw	27 - 52	olive brown (2.5Y 4/4) heavy silt loam; moderately developed coarse blocky structure; 10% coarse stones; firm soil strength; brittle; few fine roots
BC	52 – 66+	olive brown (2.5Y 4/4) sandy silt loam; apedal; massive; 30% fine to coarse stones; very firm soil strength; very few roots

Sample name: MDC 39
Soil name: Dashwood
Location: Seaview
GPS Coordinates: E2605893 N5952758
Land use: Dryland pasture
Topography: Late glacial aggradational terrace
Elevation: 27 m
Slope: 1°
Soil material: Thin loess? over gravelly alluvium
Soil drainage: Well drained
Date: 28/10/08

Horizon	Depth (cm)	Soil description
A	0 - 20	Brown (10YR 4/3) silt loam; moderately to well developed fine to medium polyhedral structure; slightly firm soil strength; friable; many fine roots
AB	20 - 30	dark yellowish brown to dark brown (10YR 4/6 + 10YR 3/3) silt loam; moderately developed polyhedral and blocky structure; weak soil strength; friable; many fine roots
Bw1	30 - 40	dark yellowish brown (10YR 3/6) silt loam; 2% medium and very coarse stones; moderately developed medium blocky structure; weak soil strength; brittle; few fine roots
Bw2	40 - 70	brown (10YR 5/3) sandy silt loam; 40% medium to coarse stones; weakly developed fine polyhedral structure; friable; few roots
BC	70 -85+	light olive brown (2.5Y 5/6) sandy gravel; 75% medium to very coarse stones; loose; single grain structure; very few roots

Sample name: MDC 40
Soil name: Kaituna
Location: State Highway 1
GPS Coordinates: E2591680 N5986121
Land use: Irrigated pasture - dairy
Topography: Flat terrace
Elevation: 30 m
Slope: 0°
Soil material: Alluvium from schist and greywacke
Soil drainage: Imperfectly drained
Date: 28/10/08

Horizon	Depth (cm)	Soil description
A	0 - 15	Dark yellowish brown (10YR 4/4) silt loam; weakly-moderately developed fine polyhedral structure; weak soil strength; friable; many fine roots; diffuse boundary
AB	15 - 24	Dark yellowish brown (10YR 4/4) heavy silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots; diffuse boundary
Bw1	24 - 46	Silty clay loam; weakly developed fine polyhedral structure friable; many fine and few coarse roots; fine faint mottles
Bw(g)	46 - 65	Silty clay loam; weakly developed fine polyhedral structure friable; medium distinct mottles
Bg	65+	Few schist stones; many mottles

Sample name: MDC 41
Soil name: Rai set
Location: Pelorus
GPS Coordinates: E2558147 N5992053
Land use: Irrigated pasture - daiying
Topography: Slightly undulating upper terrace surface
Elevation: 42 m
Slope: 2°
Soil material: Last Glaciation aggradational alluvium
Soil drainage: Well drained
Date 30/10/08

Horizon	Depth (cm)	Soil description
A	0 - 22	dark yellowish brown (10YR 4/4) silt loam; moderately developed fine polyhedral structure; 2% coarse stones; weak soil strength; friable; many fine roots
AB	22 - 32	dark yellowish brown and yellowish brown (10YR 4/4 + 10YR 5/6) silt loam; moderately developed fine polyhedral structure; 4% coarse stones; weak soil strength; friable; many fine roots
Bw1	32 - 42	yellowish brown (10YR 5/6) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; weak soil strength; friable; few fine roots
Bw2	42 - 68	yellowish brown (10YR 5/6-6/6) sandy silt loam; weakly developed coarse blocky and medium polyhedral structure; 10% medium and coarse stones; weak soil strength; brittle; few fine roots
BC	68 - 90+	yellowish brown to brownish yellow (10YR 5/6-10YR 6/8) sandy silt loam; weakly developed coarse blocky structure; 15% medium and coarse stones; very weak soil strength; friable; few fine roots

Sample name: MDC 42
Soil name: Pelorus steepland
Location: Pelorus
GPS Coordinates: E2557644 N5991434
Land use: Exotic forestry – 2^{nd} rotation
Topography: Steep slope side spur in steepland country
Elevation: 115 m
Slope: 36°
Soil material: Weathered quartzitic (greywacke) rock
Soil drainage: Well drained
Date: 30/10/08

Horizon	Depth (cm)	Soil description
A	0 - 10	dark brown and yellowish brown (10YR 3/3+ 10YR 5/6) silt loam, mixed from land\use operations; weakly developed fine polyhedral structure; 5% coarse stones; very weak soil strength; very friable; many medium and coarse roots
AB	10 - 15	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; 5% coarse stones; very weak soil strength; very friable; few fine and many coarse roots
Bw1	15 - 36	yellowish brown (10YR 5/6) heavy silt loam; weakly developed coarse blocky and medium polyhedral structure; 7% coarse and very coarse stones; slightly firm soil strength; brittle; few fine and coarse roots
Bw2	36 - 47	yellowish brown (10YR 5/8) heavy silt loam; strongly developed medium polyhedral structure; 7% coarse and very coarse stones; weak soil strength; friable; yellowish brown (10YR 5/4) distinct clay/organic coatings; few fine roots
Bw3	47 - 90	yellowish brown to brownish yellow (10YR 5/6-10YR 6/8) clay; strongly developed medium polyhedral structure; 5% coarse and very coarse stones; weak soil strength; friable; few fine roots
BC	90 - 100	90-100 cm brownish yellow (10YR 6/8) clay to clay loam; weakly developed coarse blocky and medium polyhedral structure; 5% coarse and very coarse stones; weak soil strength; friable; few fine roots
on	100+	fragmental, partly weathered greywacke siltstone

Sample name: MDC 43
Soil name: Pelorus steepland
Location: Pelorus
GPS Coordinates: E2557628 N5992080
Land use: Pasture - dairy
Topography: Steep slope planar lower slope
Elevation: 42 m
Slope: 28°
Soil material: Weathered quartzitic (greywacke) rock
Soil drainage: Well drained
Date 30/10/08

Horizon	Depth (cm)	Soil description
A	0 - 20	dark yellowish brown (10YR 4/4) silt loam; strongly developed fine polyhedral structure; 7% coarse stones; weak soil strength; very friable; many fine roots
AB	20 - 28	dark yellowish brown and yellowish brown (10YR 4/4+10YR 5/8) silt loam; strongly developed fine polyhedral structure; 7% coarse stones; weak soil strength; very friable; many fine roots
Bw1	28 - 50	yellowish brown (10YR 5/8) heavy silt loam; moderately developed fine polyhedral structure; 10% coarse and very coarse stones; weak soil strength; very friable; many fine roots
Bw2	50 - 75	yellowish brown (10YR 5/8-5/6) clay loam; moderately developed fine polyhedral structure; 10% coarse and very coarse stones; weak soil strength; friable; few fine roots
Bw3	75 - 100+	yellowish brown (10YR 5/6) clay loam; moderately developed fine polyhedral structure; 15% coarse and very coarse stones; very weak soil strength; friable; few fine roots

Sample name: MDC 44
Soil name: Manaroa
Location: Linkwater
GPS Coordinates: E2586227 N5990574
Land use: Irrigated pasture - dairying
Topography: Slightly undulating fan/fluvial surface
Elevation: 9 m
Slope: 1°
Soil material: Young schistose alluvium
Soil drainage: Well drained
Date 31/10/08

Horizon	Depth (cm)	Soil description
A	0 - 5	brown to dark brown (10YR 4/3) silt loam to silt; weakly developed fine polyhedral structure; weak soil strength; friable; many fine roots
A(g)	5 - 9	dark grayish brown silt loam to silt; weakly developed coarse blocky structure; 15% light brownish grey (10YR 6/2) and 10% dark reddish brown (5YR 3/3) fine distinct compaction mottles; weak soil strength; friable; many fine roots
A2	9 - 19	dark yellowish brown (10YR 4/4) silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; few fine roots
AB	19 - 30	olive brown and dark yellowish brown (2.5Y 4/4 + 10YR 4/4) sandy silt loam; weakly developed fine polyhedral structure; weak soil strength; friable; few fine roots
Bw1	30 - 43	light olive brown (2.5Y 5/6) silt loam to fine sandy loam; weakly developed coarse blocky structure; friable; few fine roots
BC	43 - 100	light olive brown to olive yellow (2.5Y 5/6-6/6) silt loam to fine sandy loam; apedal; massive; weak soil strength