Soil quality in Greater Wellington region 2007/08: current status of selected drystock sites and comparison with previous sampling results

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Summary

Project and Client

Greater Wellington Regional Council (GWRC), and previous to that the Wellington Regional Council (WRC), participated in the Sustainable Management Fund project "Implementing Soil Quality Indicators for Land" in 2000–2001. That project ceased in June 2001. GWRC resampled drystock sites in 2008 to determine the extent and direction of changes in soil condition. Soil quality analysis using the same protocols has also been followed by Environment Waikato, Environment BOP, and current sampling by Taranaki, Northland and Auckland Regional Councils.

The GWRC staff with responsibility for land resources resampled the original sites and supplied them to Landcare Research for analysis and interpretation.

Soil quality on the sites was appraised using a standard set of soil chemical, physical and biochemical characteristics as defined under the 500 Soils Project protocols, and currently used by other regional councils in New Zealand. A suite of metals (data supplied by GWRC) was also analysed and is included in the report.

Objectives

- Complete analyses on soil samples provided by GWRC staff.
- Provide an assessment of the current soil quality status of the soils as related to soil class and land use.
- Summarise soil metals data provided by GWRC.
- Provide interpretation of changes in soil characteristics in relation to samples taken previously.

Methods

- GWRC land resource staff resampled 23 sites that had been sampled once previously and supplied soil samples to Landcare Research.
- A standard set of 7 soil characteristics was used by Landcare Research to assess soil quality of the various soil and land-use combinations.
- Exceptional sites were identified by grouping soils under similar land uses and recording those sites that exceeded an expected range for that land use, and by comparison against expected characteristics for that soil and land use.

Results

- The 23 sites were tested for a total of 161 soil quality characteristics, 141 (88%) of which fell within target ranges. Eight of the 23 sites (35%) met all targets. Eleven sites (48%) did not meet the target range for one characteristic, three sites (13%) did not meet the target range for two characteristics, and one site (4%) did not meet the target ranges for three characteristics.

- Low macroporosity (an indication of soil compaction), was the soil quality indicator most often outside of target ranges (8 of the 20 instances where characteristics were outside of target ranges). Other indicators outside target ranges included Olsen P (5 instances of low Olsen P and 2 instances of excessively high Olsen P) and 3 instances of high total N.
- In comparison with samples taken previously, there were significant increases in pH, total carbon, total nitrogen and Olsen P. There was a significant decrease in the soil C/N ratio and no significant change in mineralisable N, bulk density, particle density and macroporosity. These changes generally reflect increased soil fertility among pasture sites.
- Soil metals were generally well below the NZWWA suggested limits except for arsenic on GW066. Total recoverable arsenic, cadmium, chromium, nickel, lead and zinc concentrations showed small but statistically significant increases in the 2008 sampling in comparison to previous samplings.

Conclusions

- The low macroporosity values on drystock sites mirror results from other regions of the country and are a general result of intensification of pastoral land-use practices. There was however no significant decrease in macroporostiy compared with the previous sampling.
- Primary concerns are (1) compaction of soils on drystock sites; (2) sub-optimal soil fertility (low Olsen P on 3 sites and high Olsen P on 2 sites) and high total nitrogen on 3 sites.
- The majority of instances of poor soil quality could be reversed by appropriate management.
- Soil metal (total recoverable arsenic, cadmium, chromium, nickel, lead, and zinc) concentrations may be increasing at small but measurable rates. Soil metals should continue to be monitored in future samplings to determine if this trend persists.

Recommendations

- GWRC should continue with its programme of resampling existing sites to determine the extent and direction of any changes since original sampling.
- To confirm samples are collected from as near as possible to the original transect, modern global positioning (GPS) should be used to locate the points as precisely as possible and the exact location (and transect layout) resampled in future samplings. This applies in particular to earlier sites that were located using NZ260 map series.
- Resampling after 3–5 years is recommended for sites undergoing rapid change (e.g., recent land-use change). Resampling after 5–10 years is recommended for sites that are stable and under long-term consistent land use and management.
- Repeat sampling on 3–4 occasions will give confidence about change on individual sites. Where equivalent land uses on similar soils can be combined, 1 or 2 further samplings should be adequate to confirm changes under that particular land use.
- Land managers are informed of the soil quality on their properties, and if remedial action is justified, they are advised on possible management strategies.
- GWRC continues activities to educate land managers on strategies to protect the environment while achieving an economic return from the land.

1. Introduction

1.1. Background

Greater Wellington Regional Council (GWRC) participated in the Sustainable Management Fund project "Implementing Soil Quality Indicators for Land" in 2000–2001. Sites sampled in 2000–2004 were resampled in 2008 and Landcare Research was contracted to analyse and interpret changes in soil quality that had occurred in the intervening years.

Soil quality was appraised using the set of 7 soil chemical, physical and biological properties that were initially measured and included the key properties and sampling protocols used by the 500 Soils Project (Sparling et al. 2001a). The various properties target the dynamic aspects of soil health, rather than land-use capability, contamination or erosion. The soil quality assessment was based on the 'fitness' of the soil for its particular use, which depended on the match between the soil capability (based on physical and chemical properties associated with soil type) and its actual use. Differences in soil characteristics since the earlier sampling are used to assess the extent and direction of change.

2. Objectives

- Complete laboratory analyses on soil samples provided by GWRC.
- Provide an assessment of the current soil quality status of the soils as related to soil class and land use.
- Summarise soil metals data provided by GWRC.
- Provide interpretation of changes in soil characteristics in relation to previous samples taken in 2000–2004.

3. Methods

Most of the methodologies have been described in earlier reports (Sparling et al. 1996, 2001a) and only brief details are given here.

3.1. Soil sampling

Soil samples were collected by GWRC staff and supplied to Landcare Research for analysis. Staff were asked to collect the soils using the protocols established in earlier sampling for the 500 Soils Project. The 23 individual samples for soil chemical and biological characteristics were analysed at the Landcare Research laboratory in Palmerston North. Soil physical analyses were completed at the Landcare Research laboratory in Hamilton. Where necessary, samples were stored at 5°C until analysis. Soil metals data (from analysis by Hill Laboratories in Hamilton) were provided to Landcare Research by GWRC.

3.2. Soil quality measurements

Seven primary soil properties were measured to assess soil quality (Table 1). Chemical and biological characteristics were assessed by the total C content, total N content, mineralisable N, Olsen P, soil pH and derived measurements such as the C/N ratio. 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.

Table 1 Indicators used for soil quality assessment

Indicators	Soil Quality Information	Method
Chemical properties		
Total C content	Organic matter status	Dry combustion, CHN Analyser
Total N content	Organic N reserves	Dry combustion, CHN Analyser
pH	Acidity or alkalinity	Glass electrode pH meter, 2.5:1 in water
Olsen P	Plant available phosphate	Bicarbonate extraction, molybdenum blue method
Biological properties		
Potentially mineralisable N	Readily mineralised N reserves	Waterlogged incubation at 40°C for 7 days
Physical properties		
Dry bulk density	Compaction, volumetric conversions	Soil cores
Particle density	calculation of porosity and available water	Specific gravity
Total and macroporosity	Soil compaction, root environment, aeration	Pressure plates

3.3. Analyses

Biochemical properties

Potentially mineralisable N was estimated by the anaerobic (waterlogged) incubation method; the increase in NH_4^+ concentration was measured after incubation for 7 days at 40°C and extraction in 2M KCl (Keeney & Bremner 1966).

Chemical properties

Total C and N were determined by dry combustion of air-dried, finely ground soils using a Leco 2000 CNS analyser. Olsen P was determined by extracting < 2 mm air-dried soils for 30 min with 0.5 M $NaHCO_3$ at pH 8.5 (Olsen et al. 1954) and measuring the PO_4^{3-} concentration by the molybdenum blue method. Soil pH was measured in water using glass electrodes and a 2.5:1 water-to-soil ratio (Blakemore et al. 1987). Soil metals data were supplied by GWRC (see appendix).

Physical properties

Macroporosity (air capacity) was determined by drainage on pressure plates at –10 kPa (Klute 1986). Dry bulk density was measured on a subsampled core dried at 105°C (Klute 1986). Macroporosity (air capacity) and total porosity were calculated as described by Klute (1986). Macroporosity in many of the previous samplings was calculated from water content at –5 kPa, for consistency, macroporosity calculated from –5 kPa was used for comparison between sampling dates.

3.4. Data presentation

All data were expressed on a weight/volume or volume/volume basis to allow comparison between soils with differing bulk density (except for metals expressed as mg/kg). Paired t-tests were used to compare change in indicator values (grouped by land use) between sampling dates

4. Results

4.1. Soils and sites

Summarised site and soil information is given in Table 2. Full site and soil profile descriptions from the original site visits are provided in the appendix. Chemical and physical data are shown in Tables 3, 4 and 5.

Table 2 Site codes, soil types, soil orders and land uses resampled in April 2008

Site code (GWRC)	LCR Code	Date First Sampled	Soil type	Subgroup, Group, Order	Land use
GW002	WRC00_02	2000	Ashurst stony silt loam	Typic Orthic Brown	Drystock
GW008	WRC00_08	2000	Te Horo silt loam	Mottled Orthic Brown	Drystock
GW012	WRC00_12	2000	Rangitikei gravelly fine sandy loam	Acidic Fluvial Recent	Drystock
GW018	WRC00_18	2000	Kokotau silt loam	Argillic Perch-gley Pallic	Drystock
GW026	WRC00_26	2000	Greytown silt loam	Acidic-weathered Fluvial Recent	Drystock
GW030	WRC01_02	2001	Martinborough loam	Mottled Immature Pallic Soil	Drystock
GW033	WRC01_05	2001	Bideford silt loam	Typic Perch-gley Pallic Soil	Drystock
GW037	WRC01_09	2001	Tauherenikau silt loam	Typic Argillic Pallic Soil	Drystock
GW043	WRC01_15	2001	Manawatu silt loam	Typic Fluvial Recent Soil.	Drystock
GW050	WRC01_22	2001	Rahui silt loam	Acid Orthic Gley Soil.	Drystock
GW054	GW03-04	2003	Makara steepland soils	Typic Orthic Brown Soil	Drystock
GW056	GW03-06	2003	Korokoro hill soils	Typic Firm Brown Soil	Drystock
GW058	GW03-08	2003	Paramata hill soils	Mottled Argillic Pallic Soil	Drystock
GW060	GW03-10	2003	Tairawhiti steepland soils	Weathered Orthic Recent Soil	Drystock
GW061	GW03-11	2003	Tinui hill soils	Mottled Orthic Brown Soil	Drystock
GW066*	GW03-16	2003	Wharekaka hill soils	Mottled Argillic Pallic Soil	Drystock
GW068	GW03-18	2003	Wharoama steepland soils	Weathered Orthic Recent Soil	Drystock
GW070	GW03-20	2003	Taihape steepland soils	Weathered Orthic Recent Soil	Drystock
GW095	GW05-01	2004	Greytown silt loam	Weathered Fluvial Recent Soil	Drystock
GW099	GW05-05	2004	Kokotau silt loam	Mottled Immature Pallic Soil	Drystock
GW106	GW05-12	2004	Greytown silt loam	Weathered Orthic Recent Soil	Drystock
GW114	GW05-20	2004	Shannon silt loam	Mottled Immature Pallic Soil	Drystock
GW118	GW05-24	2004	Te Horo stony silt loam	Typic Orthic Brown Soil	Drystock

*GWRC has advised that site GW066 was sampled at an incorrect location; therefore the results can not be interpreted against 2003 data

Table 3 Soil characteristics of sites sampled in 2008

Code	Landuse and Soil Order	pH	Total C mg/cm^3	Total N mg/cm^3	C:N ratio	Olsen P µg/cm^3	NH_4-N µg/cm^3	NO_3-N µg/cm^3	Mineralisable N µg/cm^3
GW002	Drystock, Brown Soils	5.3	88.1	**7.6**	11.5	96	77	6.3	160
GW008	Drystock, Brown Soils	6.2	51.4	4.7	10.9	33	66	0.5	133
GW012	Drystock, Recent Soils	5.8	46.4	3.9	12.0	**11**	19	2.2	125
GW018	Drystock, Pallic Soils	5.9	42.6	3.7	11.5	32	21	1.5	123
GW026	Drystock, Recent Soils	5.8	51.2	4.8	10.7	74	75	1.7	182
GW030	Drystock, Pallic Soils	6.0	43.1	4.1	10.5	43	54	4.9	142
GW033	Drystock, Pallic Soils	5.1	50.0	4.7	10.6	53	92	3.3	124
GW037	Drystock, Pallic Soils	5.8	84.8	6.7	12.6	23	54	4.4	136
GW043	Drystock, Recent Soils	5.7	51.5	5.0	10.4	56	51	0.6	172
GW050	Drystock, Gley Soils	6.0	48.8	4.4	11.0	**8**	32	0.7	153
GW054	Drystock, Brown Soils	6.5	50.5	4.3	11.6	**12**	57	0.3	114
GW056	Drystock, Brown Soils	5.6	61.3	5.1	12.1	**9**	21	2.5	144
GW058	Drystock, Pallic Soils	5.3	54.6	4.7	11.7	26	43	5.8	143
GW060	Drystock, Recent Soils	5.7	40.2	3.6	11.3	22	37	13.9	126
GW061	Drystock, Brown Soils	5.2	84.4	**7.8**	10.8	45	105	17.0	**252**
GW066**	Drystock, Pallic Soils	6.1	41.2	3.8	10.9	**14**	27	0.4	91
GW068	Drystock, Recent Soils	5.9	55.9	5.6	10.0	22	50	0.8	160
GW070	Drystock, Recent Soils	6.0	43.9	3.6	12.1	36	21	0.4	150
GW095	Drystock, Recent Soils	6.1	62.1	5.8	10.8	**110**	79	2.6	188
GW099	Drystock, Pallic Soils	**6.9**	58.0	5.8	10.0	**134**	140	0.5	158
GW106	Drystock, Recent Soils	6.1	47.8	5.0	9.6	72	184	0.4	215
GW114	Drystock, Pallic Soils	6.2	60.9	6.0	10.1	52	77	0.4	152
GW118	Drystock, Brown Soils	5.7	85.9	**7.5**	11.5	40	67	1.4	146

*Items in bold type fell outside recommended ranges for that land use and soil order

** GWRC has advised that site GW066 was sampled at an incorrect location; therefore the results can not be interpreted against 2003 data.

Table 4 Soil physical characteristics of sites sampled in 2008

Code	Land use and Soil Order	Bulk density Mg/m^3	Particle density Mg/m^3	Total porosity %v/v	Macro porosity (Air capacity) %v/v	Moisture content @–10 kPa %v/v	Moisture content @–5 kPa %v/v
GW002	Drystock, Brown Soils	0.99	2.37	58.4	14.7	43.8	48.3
GW008	Drystock, Brown Soils	1.08	2.52	57.3	14.3	43.0	45.4
GW012	Drystock, Recent Soils	1.24	2.62	52.7	16.4	36.3	39.2
GW018	Drystock, Pallic Soils	1.28	2.62	51.3	**8.5**	42.8	45.1
GW026	Drystock, Recent Soils	1.23	2.63	53.4	10.9	42.5	44.8
GW030	Drystock, Pallic Soils	1.24	2.60	52.6	13.7	38.9	41.2
GW033	Drystock, Pallic Soils	1.29	2.57	49.9	**9.7**	40.2	42.6
GW037	Drystock, Pallic Soils	0.77	2.40	67.9	25.4	42.5	46.1
GW043	Drystock, Recent Soils	1.19	2.60	54.3	**8.1**	46.2	48.7
GW050	Drystock, Gley Soils	0.97	2.54	61.6	**10.0**	51.7	55.1
GW054	Drystock, Brown Soils	0.97	2.51	61.1	17.2	43.9	47.1
GW056	Drystock, Brown Soils	0.91	2.45	62.7	19.0	43.8	47.3
GW058	Drystock, Pallic Soils	1.22	2.53	51.8	12.0	39.9	41.8
GW060	Drystock, Recent Soils	1.13	2.56	56.0	22.0	34.1	40.9
GW061	Drystock, Brown Soils	0.98	2.46	60.2	15.0	45.2	47.0
GW066**	Drystock, Pallic Soils	1.10	2.57	57.1	16.5	40.6	43.3
GW068	Drystock, Recent Soils	1.03	2.50	58.7	14.6	44.0	45.9
GW070	Drystock, Recent Soils	1.25	2.59	51.8	10.1	41.7	43.7
GW095	Drystock, Recent Soils	1.29	2.61	50.5	**8.6**	41.9	43.7
GW099	Drystock, Pallic Soils	1.15	2.56	55.2	**7.0**	48.2	49.9
GW106	Drystock, Recent Soils	1.33	2.63	49.5	**9.1**	40.4	41.8
GW114	Drystock, Pallic Soils	1.18	2.54	53.6	**4.7**	48.9	51.4
GW118	Drystock, Brown Soils	0.92	2.39	61.5	18.1	43.4	48.0

*Items in bold type fell outside recommended ranges for that land use and soil order

** GWRC has advised that site GW066 was sampled at an incorrect location; therefore the results can not be interpreted against 2003 data.

Table 5 Soil heavy metal content (total recoverable) of sites sampled in 2008 (data supplied by GWRC)

Code	Land Use and Soil Class	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper Mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg
GW002	Drystock, Brown Soils	3.1	0.48	12	6.4	5.1	9.6	52
GW008	Drystock, Brown Soils	3.2	0.20	16	13.0	10.0	14.0	68
GW012	Drystock, Recent Soils	8.5	0.12	18	15.0	17.0	39.0	120
GW018	Drystock, Pallic Soils	3.1	0.19	15	8.7	10.0	12.0	61
GW026	Drystock, Recent Soils	6.3	0.26	20	25.0	20.0	24.0	93
GW030	Drystock, Pallic Soils	<2.0	0.30	10	3.0	6.3	8.8	43
GW033	Drystock, Pallic Soils	2.7	0.20	15	7.6	9.2	9.1	51
GW037	Drystock, Pallic Soils	3.3	0.45	12	8.5	5.3	13.0	51
GW043	Drystock, Recent Soils	7.2	<0.10	17	23.0	15.0	25.0	88
GW050	Drystock, Gley Soils	4.8	0.34	17	13.0	9.5	20.0	58
GW054	Drystock, Brown Soils	2.3	0.19	9	5.3	5.6	6.7	31
GW056	Drystock, Brown Soils	3.7	0.16	12	7.9	7.7	11.0	51
GW058	Drystock, Pallic Soils	3.1	0.17	9	4.7	4.4	18.0	36
GW060	Drystock, Recent Soils	<2.0	<0.10	8	3.8	4.6	6.6	32
GW061	Drystock, Brown Soils	2.6	0.40	16	8.8	9.7	8.1	62
GW066**	Drystock, Pallic Soils	**23.0**	0.14	11	11.0	6.3	11.0	51
GW068	Drystock, Recent Soils	6.1	0.18	12	12.0	11.0	12.0	67
GW070	Drystock, Recent Soils	6.3	0.12	12	9.8	8.6	12.0	54
GW095	Drystock, Recent Soils	7.9	0.15	20	21.0	20.0	43.0	110
GW099	Drystock, Pallic Soils	4.7	0.39	21	10.0	15.0	15.0	75
GW106	Drystock, Recent Soils	6.0	0.21	21	18.0	21.0	18.0	85
GW114	Drystock, Pallic Soils	3.4	0.55	17	13.0	11.0	9.2	68
GW118	Drystock, Brown Soils	2.7	0.60	10	8.6	4.5	17.0	49

*Items in bold type fell outside recommended ranges

** GWRC has advised that site GW066 was sampled at an incorrect location; therefore the results can not be interpreted against 2003 data.

4.2. Overall soil quality

The 23 sites were tested for a total of 161 soil quality characteristics. For all indicators across all sites, 88% (141 out of 161) fell within target ranges. Eight of the 23 sites (35%) met all targets (Fig. 1). Eleven sites (48%) did not meet the target range for one characteristic, three sites (13%) did not meet the target range for two characteristics, and one site (4%) did not meet the target ranges for three characteristics.

4.3 Soil chemical characteristics

Soil chemical characteristics accounted for 12 of the 20 indicators that fell outside target ranges (Fig 2). Olsen P accounted for the majority of these cases: five sites where Olsen P was below target values (GW12, GW50, GW54, GW56 and GW66) and two sites where Olsen P values were excessively high (GW095 and GW099). Low Olsen P values, when maintained over long time periods, can result in decreased pasture growth and possible erosion from overgrazing, whereas high Olsen P values increase the risk of P entering waterways and adversely affecting water quality.

Total nitrogen was high on three sites (GW2, GW61 and GW118) and, similar to high Olsen P, could result in excess N leaching into waterways. Soil pH and mineralisable nitrogen were above the target range on one site each (GW099 and GW61 respectively).

4.4 Soil physical characteristics

Eight of the 23 sites monitored (35%) had macroporosity values less than the target range of 10% (Table 4) indicating compacted soils. Sites with low macroporosity were: GW018, GW033, GW043, GW095, GW099, GW106 and GW114. As noted in previous reports, macroporosity below 10% may inhibit pasture production (Drewery 1999; Singleton 2000) and remains one of the largest concerns on dairy and drystock sites.

4.5 Soil heavy metal concentrations

Soil heavy metal concentrations varied across sites (Table 5). Natural concentrations of most metals can vary greatly depending on geologic parent material. The New Zealand Water and Wastes Association (NZWWA 2003) suggested limits for land biosolid application provide some guidelines on acceptable heavy metal concentrations in soils. The NZWWA suggests upper soil limits (in mg metal concentration per kg dry weight soil) of: 20 mg/kg for arsenic (As), 1 mg/kg for cadmium (Cd), 600 mg/kg for chromium (Cr), 100 mg/kg for copper (Cu), 300 mg/kg for lead (Pb), 60 mg/kg for nickel (Ni), and 300 mg/kg for zinc (Zn).

Measured concentrations of total recoverable metals at all sites were below the NZWWA guidelines except GW066 which had an arsenic level of 23 mg/kg (GWRC advised that this site was not sampled at the same location as the previous sampling, we have reported the data for the current soil quality sampling, but have not used this site in comparison to the previous sampling).

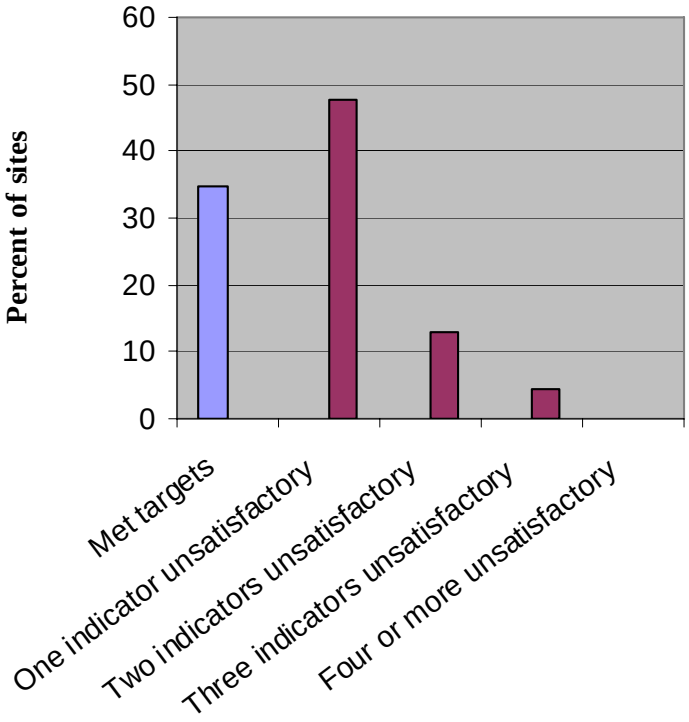

Fig. 1 Percentage of all sites (23 sites monitored) that met targets for soil quality indicators

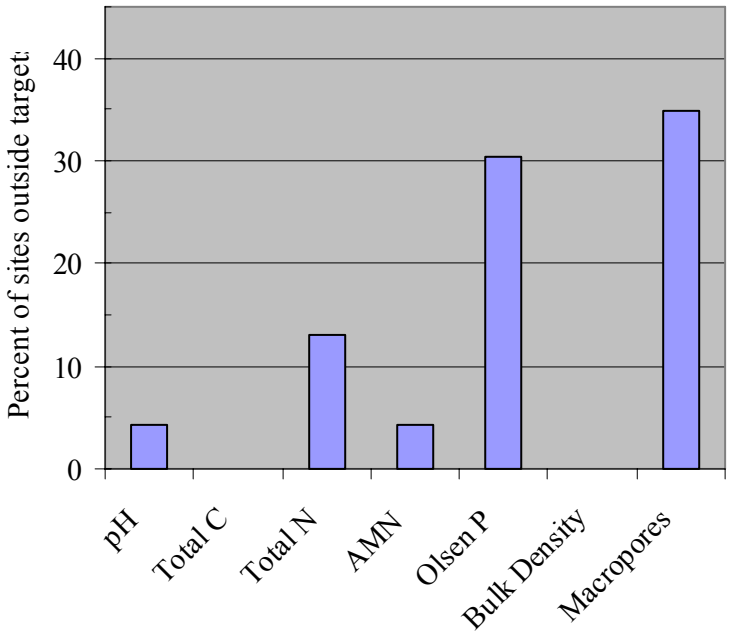

Fig. 2 Percentage of all sites (23 sites monitored) that failed to meet target ranges for specific indicators

4.6 Changes in soil quality since previous sampling

The current data were compared against those obtained in the previous sampling (Sparling et al. 2000a, 2002; Sparling 2003, 2005) to determine the extent and direction of any change. The volumetric data used for comparison between each sampling period are provided in the appendix. The difference for each indicator between the current and previous sampling is shown in Table 6a. Comparison of soil metals are contained in Table 7a. The data in the tables are presented as the accumulated change (Sum), the standard deviation as a measure of variance, and the mean to show the averaged change (in units for that particular indicator) across all sites in the group. Resampled sites spanned a relatively large number of years (2000–2004). Tables 6b and 7b (for soil quality indicators and soil metals respectively) show the sum, standard deviation and mean for data grouped by sampling date (2000–2001 and 2003–2004) in order to gauge if time since resampling had an effect on the magnitude of change.

Average change for each indicator (for all sites) is shown in Figures 3, and average change in soil metal concentrations in Figure 4.

Drystock sites

The large number of drystock sites resampled at the same time enabled increased power to determine statistically significant changes in the data. Over all resampled sites (Table 6a), there were statistically significant increases in pH, total carbon, total nitrogen, and Olsen P. There was a significant decrease in the soil C/N ratio and no significant change in mineralisable N, bulk density, particle density and macroporosity. When viewed by date of sampling (Table 6b), the summary statistics indicated no clear trend for the date of sampling (e.g., sites sampled in 2001–2002 did not generally show larger changes than those sites sampled in 2003–2004). The overall results (particularly higher total N and Olsen P and lower C/N ratios) generally confirm the trend of increasing soil fertility.

Soil total recoverable metals also showed statistically significant increases (Table 7a). Arsenic, cadmium, chromium, nickel, lead, and zinc concentrations were all significantly higher in the 2008 sampling than the previous sampling. As with soil quality indicators, there was no indication that sites sampled in 2000 and 2001 had a larger increase in soil metals than sites sampled in 2003 and 2004 (Table 7b). While the observed increases in metals were generally small (and levels for most metals well below the upper limits suggested by the NZWWA), if this trend is observed to continue in future samplings, it may be cause for concern over long time spans.

Table 6a Changes in soil quality attributes of drystock soils between 2008 and the previous sampling

Site	Date Previously Sampled	Soil Order	pH	Total C mg/cm^3	Total N mg/cm^3	Mineralisable N µg/cm^3	Olsen P µg/cm^3	C/N ratio	Dry bulk density Mg m^3	Particle density Mg m^3	Macroporosity (–5 kPa) %v/v
GW002	2000	Brown Soils	0.1	5.2	0.7	–38	27	–0.3	0.07	–0.03	–1.2
GW008	2000	Brown Soils	0.9	5.1	0.5	–16	11	–0.1	–0.02	0.02	4.0
GW012	2000	Recent Soils	0.4	6.6	0.7	20	3	–0.4	0.28	0.12	–11.5
GW018	2000	Pallic Soils	0.4	3.0	0.4	23	18	–0.4	–0.02	0.02	0.6
GW026	2000	Recent Soils	–0.2	4.0	0.9	0	44	–1.5	–0.06	0.01	2.3
GW030	2001	Pallic Soils	0.2	–0.6	0.3	34	31	–1.1	0.11	0.07	5.7
GW033	2001	Pallic Soils	-0.5	13.5	1.6	22	17	–1.3	0.14	0.02	3.1
GW037	2001	Pallic Soils	0.1	**28.1**	1.8	–2	7	1.2	–0.05	0.00	10.3
GW043	2001	Recent Soils	0.1	3.0	0.6	–39	-1	–0.8	0.03	–0.01	–1.1
GW050	2001	Gley Soils	–0.9	–14.2	–1.1	–266	–24	–0.3	–0.10	–0.01	–11.2
GW054	2003	Brown Soils	1.4	-6.2	0.5	38	2	–3.3	–0.26	–0.02	10.4
GW056	2003	Brown Soils	0.3	2.2	0.5	53	2	–0.7	0.04	–0.03	5.1
GW058	2003	Pallic Soils	0.0	5.5	0.7	52	2	–0.5	0.14	–0.01	0.6
GW060	2003	Recent Soils	0.2	4.3	0.8	46	8	–1.6	0.03	–0.08	–9.9
GW061	2003	Brown Soils	-0.1	**24.4**	2.6	137	28	–0.8	–0.14	–0.15	–2.3
GW066	2003	Pallic Soils	na[1]	na	na	na	na	na	na	na	na
GW068	2003	Recent Soils	0.4	12.1	1.8	61	9	–1.5	–0.13	–0.06	1.5
GW070	2003	Recent Soils	0.5	4.0	0.4	50	8	–0.4	0.01	0.01	–4.3
GW095	2004	Recent Soils	0.1	**24.2**	2.1	52	45	0.5	0.10	–0.01	4.2
GW099	2004	Pallic Soils	0.5	17.4	1.9	54	74	–0.5	–0.09	–0.04	4.3
GW106	2004	Recent Soils	0.0	11.5	1.3	91	23	–0.2	–0.05	–0.02	4.1
GW114	2004	Pallic Soils	0.0	15.6	1.9	54	28	–0.8	0.14	0.01	–0.9
GW118	2004	Brown Soils	0.6	–4.0	–0.3	–18	–27	–0.1	–0.09	–0.02	9.9
		Sum	4.2	164.7	20.5	407	332	-14.9	0.07	-0.19	23.7
		sd	0.4	10.2	0.9	76	22	0.9	0.12	0.05	6.2
		Mean	0.2*	7.5*	0.9*	18	15*	-0.7*	0.00	-0.01	1.1

*Statistically significant change from previous sampling ($P<0.05$)

[1]GWRC advised that this site was sampled at an incorrect location, therefore data not used in comparison with previous sampling

Bolded numbers indicate particularly large changes

Table 6b Changes in soil quality attributes of drystock soils between 2008 and the previous sampling based on sampling date

Date Previously Sampled	Soil Order	pH	Total C mg/cm^3	Total N mg/cm^3	Mineralisable N $\mu g/cm^3$	Olsen P $\mu g/cm^3$	C/N ratio	Dry bulk density $Mg\ m^3$	Particle density $Mg\ m^3$	Macroporosity (-5 kPa) %v/v
2000-2001	Sum	0.51	53.7	6.3	–262	131	–5.0	0.36	0.22	1.0
(n=10)	Sd	0.48	10.6	0.8	88	19	0.7	0.11	0.05	6.9
	Mean	0.05	5.4	0.6	–26	13	–0.5	0.04	0.02	0.1
2003-2004	Sum	3.71	111.0	14.2	668	201	–9.9	–0.29	–0.41	22.7
(n=12)	Sd	0.41	10.0	0.9	35	25	1.0	0.12	0.04	5.8
	Mean	0.31	9.3	1.2	56	17	–0.8	–0.02	–0.03	1.9

Table 7a Changes in soil total recoverable metal concentrations of drystock pasture soils between 2008 and the previous sampling

Code	Date previously Sampled	Soil Order	Arsenic mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg
GW002	2000	Brown Soils	0	0.08	4	0	1.1	1.2	10
GW008	2000	Brown Soils	0	0.10	2	3	1	3.6	11
GW012	2000	Recent Soils	3	0.02	3	–1	3	5	29
GW018	2000	Pallic Soils	0	-0.01	2	0	1	2	7
GW026	2000	Recent Soils	na[1]	na	na	na	na	na	na
GW030	2001	Pallic Soils	0	0.20	3	–1	1.3	–3	9
GW033	2001	Pallic Soils	1	0.00	3	0	2.2	0.7	6
GW037	2001	Pallic Soils	–1	0.15	2	0	–0.7	–1.8	3
GW043	2001	Recent Soils	–1	-0.05	1	-5	0	–0.6	4
GW050	2001	Gley Soils	3	0.04	5	2	2	10.3	6
GW054	2003	Brown Soils	0	0.14	0	1	1	–0.5	7
GW056	2003	Brown Soils	1	0.11	3	3	3	3.2	24
GW058	2003	Pallic Soils	–1	0.07	–2	–1	–1	6.8	2
GW060	2003	Recent Soils	0	0.00	3	1	2	0.1	12
GW061	2003	Brown Soils	1	0.20	2	4	1	-0.5	12
GW066	2003	Pallic Soils	na	na	na	na	na	na	na
GW068	2003	Recent Soils	2	0.08	0	3	1	1.2	14
GW070	2003	Recent Soils	0	0.07	0	1	1	1.2	4
GW095	2004	Recent Soils	2	0.10	3	–1	4	18.8	25
GW099	2004	Pallic Soils	2	0.09	3	–4	1	1.3	–4
GW106	2004	Recent Soils	1	0.01	1	-6	3	1.9	2
GW114	2004	Pallic Soils	0	0.25	4	2	2	0.8	12
GW118	2004	Brown Soils	0	0.20	1	–1	1	2.2	5
		Sum	13.0	1.85	43	-1.9	27.5	53.9	200.0
		Sd	1.2	0.08	2	2.6	1.2	4.7	8.1
		Avg	0.6*	0.09*	2*	-0.1	1.3*	2.6*	9.5*

[1]Previous data for site GW026 not available, GW066 not used in comparison as previously explained

*Statistically significant change from previous sampling ($P<0.05$)

Table 7b Changes in soil total recoverable metal concentrations of drystock pasture soils between 2008 and previous sampling based on sampling date.

Date Previously Sampled		Arsenic Mg/kg	Cadmium mg/kg	Chromium mg/kg	Copper mg/kg	Nickel mg/kg	Lead mg/kg	Zinc mg/kg
2000-2001 (n=9)	sum	5.0	0.5	25.0	-2.8	10.0	17.4	85.0
	sd	1.5	0.1	1.2	2.2	1.2	4.0	7.8
	avg	0.6	0.1	2.8	-0.3	1.1	1.9	9.4
2003-2004 (n=12)	sum	8.0	1.3	18.2	0.9	19.0	36.5	115.0
	sd	1.0	0.1	1.7	2.9	1.3	5.3	8.7
	avg	0.7	0.1	1.5	0.1	1.6	3.0	9.6

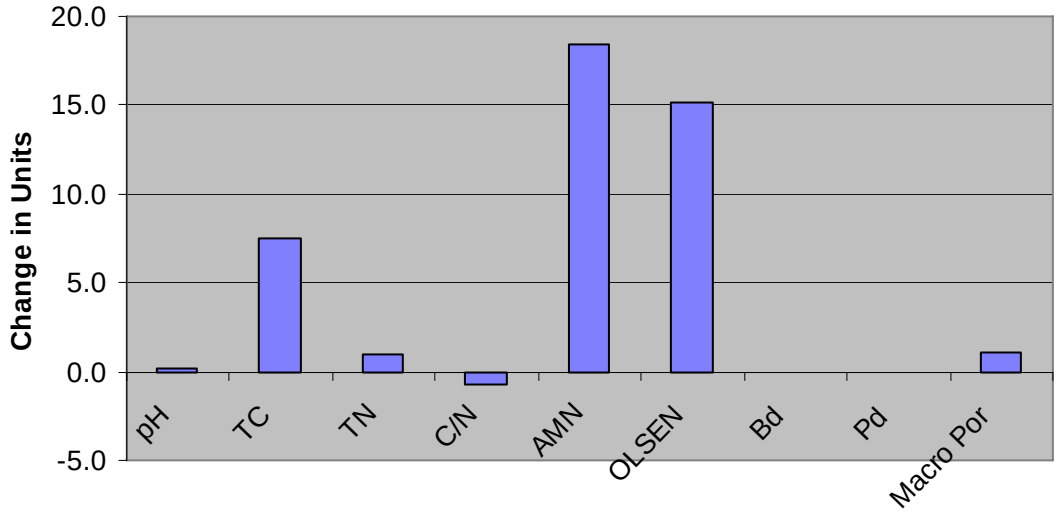

Fig. 3 Average change in soil quality attribute units between sampling periods

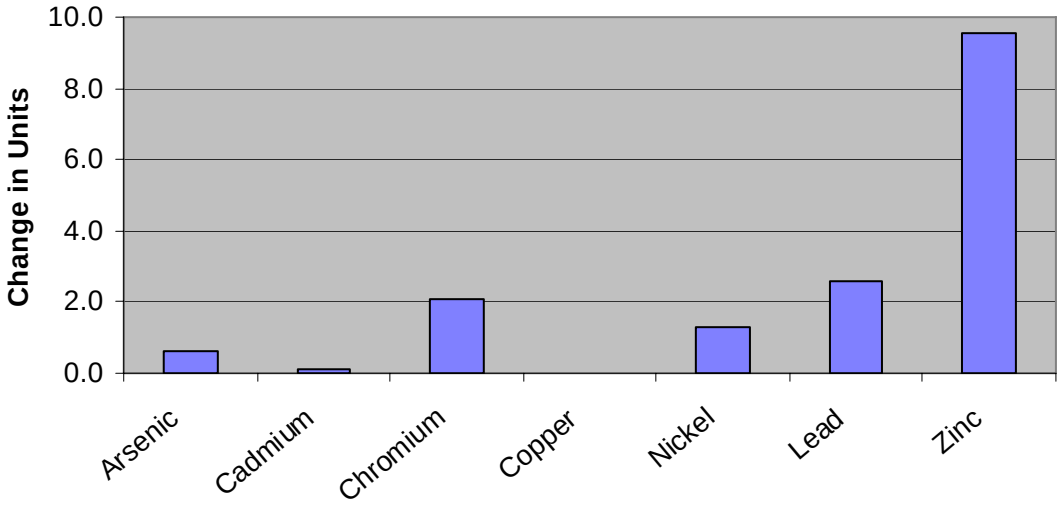

Fig. 4 Average change in soil total recoverable metals (mg/kg) between sampling periods

5. Discussion

Soil quality characteristics of sites sampled in 2008 followed many trends seen in other samplings. Low macroporosity values (indicating soil compaction) and suboptimal nutrient levels (high total N and variable Olsen P) continue to be the main issues for pasture soils.

The large number of drystock sites resampled at one time enabled increased power to determine significant changes between sampling periods. However, unlike trends in previous years, there was no overall decline in macroporosity or soil carbon between sampling periods.

As noted in previous reports, data from resampled sites showed several excessively large differences, particularly in total carbon, suggesting apparent changes (both positive and negative) should be interpreted cautiously until more data are obtained and consistent trends are recorded. Although Sparling and Schipper (1998) noted coefficients of variation for chemical indicators along a transect (at a single sampling period) were generally less than 10%, we have encountered changes in values between sampling periods that are larger (particularly for total soil carbon). The fact that there was generally not greater change in resampled sites from 2000–2001 compared with those resampled in 2003–2004 suggests some changes may be more episodic in nature rather than gradual. Several of the sites which showed excessively large changes in soil carbon (GW037 and GW095 Recent Soils on river terraces and GW095 on a hillslope terrace) could be susceptible to erosional deposition or flooding which could conceivably explain such large changes. Once sites are sampled between three and five times we will be better able to gauge the nature of progressive changes in individual sites. In the interim, we stress the importance of precise relocation of sampling sites and strict adherence to the 500 soils sampling protocol in order to minimise variation between sampling periods.

Soil metal concentrations were generally well below the suggested NZWWA limits, the one exception being arsenic at site GW066 (as noted throughout the report however, GWRC has advised that site was not sampled at the original location). There was however, a small but statistically significant increase in arsenic, cadmium, chromium, nickel, lead, and zinc concentrations in the 2008 sampling in comparison to the earlier samplings. If the trend continues to be observed in future sampling, this may be cause for concern.

A recent workshop (Agri-Environmental Indicators, April 2008) indicated the need ‘to provide information and analysis on understanding the linkages between agriculture and the environment to help governments design and implement environmentally effective and economically efficient policies’. Earlier soil quality reports (e.g., Sparling et al. 2001b, 2004; Sparling & Schipper 2004) highlighted issues such as widespread compaction of dairy farm soils and suboptimal soil fertility, and gave examples of possible management options including run-off pads on dairy farms, rapid movement of cattle to minimise pugging, on-farm nutrient budgeting, disposal of effluent only onto suitable land and at rates that allow adequate treatment, greater return of crop residues, and use of minimum and zero tillage in arable farming. All the soil quality characteristics reported can be modified (reversed) by suitable management and education of land owners and land managers is an integral part of this strategy.

6. Conclusions

- The low macroporosity values on drystock sites mirror results from other regions of the country and are a general result of intensification of pastoral land-use practices. There was, however, no significant decrease in macroporostiy in comparison to previous samplings.
- Primary concerns are (1) compaction of soils on drystock sites; (2) sub–optimal soil fertility (low Olsen P on 3 sites and high Olsen P on 2 sites) and high total nitrogen on 3 sites.
- The majority of instances of poor soil quality can be reversed by appropriate management.
- Soil metal (total recoverable arsenic, cadmium, chromium, nickel, lead and zinc) concentrations may be increasing at a small but measurable rate. Soil metals should continue to be monitored in future samplings to determine if this trend persists.

7. Recommendations

- GWRC should continue with its programme of resampling existing sites to determine the extent and direction of any changes since original sampling.
- To confirm samples are collected from as near as possible to the original transect, modern global positioning (GPS) should be used to locate the points as precisely as possible and the exact location (and transect layout) resampled in future samplings. This applies in particular to earlier sites that were located using NZ260 map series.
- Resampling after 3–5 years is recommended for sites undergoing rapid change (e.g., recent land-use change). Resampling after 5–10 years is recommended for sites that are stable and under long-term consistent land use and management.
- Repeat sampling on 3–4 occasions will give confidence about change on individual sites. Where equivalent land uses on similar soils can be combined, 1 or 2 further samplings should be adequate to confirm changes under that particular land use.
- Land managers are informed of the soil quality on their properties, and if remedial action is justified, they are advised on possible management strategies.
- GWRC continues activities to educate land managers on strategies to protect the environment while achieving an economic return from the land.

8. Acknowledgements

Soil chemical analyses were completed at the Environmental Chemistry Laboratory, Landcare Research, Palmerston North. Soil physical analyses were completed by the Soil Physics Laboratory, Landcare Research, Hamilton. Paul Sorensen (GWRC) selected sites, contacted landowners and conducted soil sampling.

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10. Appendices

Site and soil descriptions from original samplings

Soil Chemical and Physical Analysis Data Tables

Site WRC00_2 (GW002)

Ident:	**WRC 00_2**
Soil type:	Ashhurst stony silt loam
Map reference:	NZMS260 S25 2689343, 6043849 (±5 m)
GPS Coordinates	E2689308 N6043836 (2008)
Location:	Walkers, Te Waka Rd, 3.5km SSW of Otaki.
Transect length and direction (deg.):	25 m; 60° T
Local contact person:	Debbie and Nigel Walker
Local contact address or telephone:	Te Waka Road 06 364 3287
Classification:	Typic Orthic Brown Soil
Land use:	Pastoral farming.
Date sampled:	13 November 2000
Land–use history:	18 years deer, but drystock since 1998
Present vegetation:	Pasture
Slope:	0°
Aspect:	Not applicable
Landform:	Surface of terrace, in terrace country
Annual rainfall:	1100 mm
Elevation:	20 m
Parent material:	Coarse-textured greywacke alluvium on deep alluvial gravels
Drainage:	Well drained
Topsoil depth:	0.19 m
Total rooting depth:	0.6 m
Limiting horizon (nature & depth):	Compact gravels at < 1m depth
Sampled by (name & organisation):	R. H. Wilde (Landcare Research)
Author:	R. H. Wilde

Description:WRC 00_2

Ap 0–19 cm	dark yellowish brown (10YR3/4) stony silt loam; dry; common medium and coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); slightly firm soil strength; brittle failure; moderately developed pedality with abundant medium polyhedral-shaped primary peds, abundant extremely fine fibrous interpedal roots; indistinct boundary.
ABw 19–30 cm	dark brown (10YR4/4) stony silt loam; dry; common 8-mm-diam. distinct (10YR3/4) casts; many medium and coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); weak soil strength; brittle failure; moderately developed pedality with many medium polyhedral-shaped primary peds, abundant extremely fine fibrous interpedal roots; indistinct boundary.
Bw 30–50 cm	dark brown (10YR4/4) stony clay loam; moist; no mottles; many medium and coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); weakly weathered, non-indurated, silty-textured fluvial parent material with gravels; weak soil strength; brittle failure; moderately developed pedality with many fine polyhedral-shaped primary peds, no coatings; many extremely fine fibrous interpedal roots; diffuse boundary.
C 50+ cm	dark yellowish brown (10YR3/4) stony coarse sand; moist; abundant medium and coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); very few fine roots.

Site WRC00_8 (GW008)

Ident:	**WRC 00_8**
Soil type:	Te Horo silt loam
Map reference:	NZMS260 S25 2690474, 6041783 (±5 m)
GPS Coordinates	E2690463 N6041795 (2008)
Location:	Tom Richardson's property, Hautere Cross Rd, 6 km S of Otaki
Transect length and direction (deg.):	15 m; 115° T
Local contact person:	Tom Richardson
Local contact address or telephone:	Ngakoro Land Co Ltd, c/ Tom Richardson, Hautere Cross Road, 06 364 2100
Classification:	Mottled Orthic Brown Soil
Land use:	Pastoral farming
Date sampled:	15 November 2000
Land–use history:	Long–term drystock after deer farming
Present vegetation:	Pasture
Slope:	0.5°
Aspect:	0°
Landform:	Surface of terrace, in terrace country
Annual rainfall:	1100 mm
Elevation:	60 m
Parent material:	Fine-textured greywacke alluvium on deep alluvial gravels
Drainage:	Moderately well drained
Topsoil depth:	0.18 m
Total rooting depth:	0.75 m
Limiting horizon (nature & depth):	Impeding silt loam
Sampled by (name & organisation):	R. H. Wilde (Landcare Research)
Author:	R. H. Wilde

Description: WRC 00_8

Ap 0–18 cm	Dark brown (10YR4/3) silt loam; slightly moist; slightly weathered subrounded medium greywacke gravels (<200 mm diam.); strongly developed pedality with abundant fine polyhedral-shaped primary peds, no coatings; abundant extremely fine fibrous interpedal roots; distinct boundary.
Bw 18–32 cm	yellowish-brown (10YR5/4) silt loam; slightly moist; no mottles; no gravels (<200 mm diam.); no boulders (>200 mm diam); strongly developed pedality with abundant fine polyhedral-shaped primary peds; no coatings; few extremely fine fibrous interpedal roots; indistinct boundary.
Bwg 32–75 cm	yellowish–brown (10YR5/6) silt loam; moist; few 4 mm diam. distinct (7.5YR4/6) mottles; no gravels (<200 mm diam.); no boulders (>200 mm diam); non-indurated silty textured fluvial parent materials with slight weathering; moderately developed pedality with common medium polyhedral-shaped primary peds, no coatings; few extremely fine fibrous interpedal roots; indistinct boundary.
Bg 75+ cm	yellowish-brown (10YR5/6) silt loam; moist; few 8 mm diam. prominant (2.5Y6/4) mottles; no gravels (<200 mm diam.); no boulders (>200 mm diam); weakly weathered, non-indurated silt-textured fluvial parent materials, frequently containing gravels; no coatings; few roots; no boundary observed.

Site WRC00_12 (GW012)

Ident:	**WRC 00_12** (WRC site 51)
Soil type:	Rangitikei gravelly fine sandy loam
Map reference:	NZMS260 S25 2690994, 6046429 (±5 m).
GPS Coordinates	E2690962 N6046429 (2008)
Location:	WRC flood control depot, near SH 1 1 km S of Otaki
Transect length and direction (deg.):	50 m, 304 °
Local contact person:	Geoff Dick, Wellington Regional Council
Local contact address or telephone:	Wellington Regional Council Flood Control depot, Moana Rd, Otaki. Ex. 8329
Classification:	Acidic Fluvial Recent Soil
Land use:	Pastoral farming
Date sampled:	16 November 2000
Land–use history:	Long-term drystock farming
Present vegetation:	Pasture
Slope:	1°
Aspect:	180°
Landform:	Surface of low terrace, in terrace country
Annual rainfall:	1000 mm
Elevation:	20 m
Parent material:	Fine-textured greywacke alluvium with gravels on deep alluvium
Drainage:	Excessively drained
Topsoil depth:	0.1 m
Total rooting depth:	1+ m
Limiting horizon (nature & depth):	None encountered
Sampled by (name & organisation):	R. H. Wilde (Landcare Research)
Author:	R. H. Wilde

Description: WRC 00_12

Ap 0–10 cm:	dark greyish brown (10YR4/2) fine sandy loam; dry; no mottles; few medium slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); weak soil strength; friable failure; moderately developed pedality with many fine polyhedral-shaped primary peds, abundant extremely fine fibrous interpedal roots; indistinct boundary.
Bw 10–18 cm	dark greyish brown (10YR4/2) fine sandy loam; dry; no mottles; few medium slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); weak soil strength; friable failure; moderately developed pedality with many fine polyhedral-shaped primary peds, no coatings; common extremely fine fibrous interpedal roots; distinct boundary.
C 18+ cm	dark greyish brown (10YR4/2) sandy loam; dry; no mottles; many coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); no boulders (>200 mm diam); non-indurated, slightly altered, loamy-textured fluvial parent material with gravels; weak soil strength; friable failure; weakly developed pedality with common fine polyhedral-shaped primary peds, few extremely fine fibrous interpedal roots.

Site WRC00_18 (GW018)

Ident:	**WRC 00_18**
Soil type:	Kokotau silt loam
GPS Coordinates	E2729445 N6019973 (2008)
Map reference:	NZMS260 S26 2729502, 6020060 (±6 m)
Location:	David Lowe's property, Perry's Rd, 8 km ENE of Carterton. Profile is located in paddock opposite David Lowe's house, near bend in road
Transect length and direction (deg.):	50 m,
Local contact person:	David Lows
Local contact address or telephone:	Perry's Road, near corner with East Taratahi Rd. (06) 378–2467
Classification:	Argillic Perch-gley Pallic Soil
Land use:	Pastoral farming
Date sampled:	22-Nov-00
Land-use history:	150 years drystock pasture
Present vegetation:	Pasture
Slope:	0°
Aspect:	Not applicable
Landform:	Surface of terrace, in terrace country
Annual rainfall:	900 mm
Elevation:	100 m
Parent material:	Fine-textured greywacke loess on deep loess.
Drainage:	Imperfectly drained
Topsoil depth:	0.22 m
Total rooting depth:	0.6 m
Limiting horizon (nature & depth):	Strongly gleyed, Bg horizon at c.60 cm
Sampled by (name & organisation):	R. H. Wilde (Landcare Research)
Author:	R. H. Wilde

Description: WRC 00_18

Ap 0–22 cm	very dark greyish brown (10YR3/2) silt loam; slightly moist; very few 2 mm diam. faint (10YR5/6) mottles; no gravels; firm soil strength; brittle failure; moderately developed pedality with common fine polyhedral-shaped primary peds; many extremely fine fibrous interpedal roots; distinct boundary.
ABw 22–32 cm	yellowish-brown (10YR5/4) silty clay loam; slightly moist; common 8 mm diam. faint (10YR3/2 casts) mottles; brittle failure; moderately developed pedality with many fine polyhedral-shaped primary peds; common extremely fine fibrous interpedal roots; indistinct boundary.
ABw(g) 32–58 cm	yellowish-brown (10YR5/4) clay loam; moist; common 4 mm diam. faint (7.5YR4/6) mottles; brittle failure; moderately developed pedality with many fine polyhedral-shaped primary peds; common extremely fine fibrous interpedal roots; diffuse boundary.
Bg1 58–75 cm	greyish brown (2.5Y5/2) silty clay; moist; many 8 mm diam. prominent (7.5YR5/8) mottles; firm soil strength; moderately developed pedality with many medium & fine polyhedral-shaped primary peds; few extremely fine fibrous interpedal roots; diffuse boundary.
Bg2 75–100 cm	light olive grey (5Y6/2) silty clay; moist; abundant 15 mm diam. prominent (7.5YR5/8) mottles; non-indurated silty textured fluvial parent material with moderate alteration; firm soil strength; moderately developed pedality with common medium & fine blocky-shaped primary peds; no coatings; few microfine fibrous interpedal roots; diffuse boundary.
D 100+ cm	slightly moist; profuse very coarse slightly weathered subrounded greywacke gravels (<200 mm diam.); few small slightly weathered subrounded greywacke boulders (>200 mm diam.).

Site WRC00_26 (GW026)

Ident:	**WRC 00_26**
Soil type:	Greytown silt loam
Map reference:	NZMS260 T26 2733057, 6026769 (±6 m)
GPS Coordinates	E2733079 N6026801 (2008)
Location:	David Bulman's property, Akura Rd, 2 km west of Masterton
Transect length and direction (deg.):	50 m, 304° T
Local contact person:	David Bulman
Local contact address and telephone:	42 Cooper St, Masterton 06 377 4221
Classification:	Acidic-weathered Fluvial Recent Soil
Land use:	Pastoral farming
Date sampled:	15 May 2001
Land–use history:	Grazing (40 years)
Present vegetation:	Pasture
Slope:	0°
Aspect:	Not applicable
Landform:	Surface of low terrace, in terrace country
Annual rainfall:	900 mm
Elevation:	113 m
Parent material:	Fine-textured greywacke alluvium on deep alluvium
Drainage:	Moderately well to imperfectly drained
Topsoil depth:	0.25 m
Total rooting depth:	1 m
Limiting horizon (nature & depth):	None encountered
Sampled by (name & organisation):	R. H. Wilde (Landcare Research)
Author:	R. H. Wilde

Description: WRC 00_26

Ap 0–25 cm	black (10YR2/1) silt loam; slightly moist; firm soil strength; semi-deformable failure; moderately plastic; non-sticky; strongly developed pedality with abundant coarse polyhedral-shaped primary peds; abundant extremely fine fibrous ubiquitous roots; indistinct boundary.
AB 25–37 cm	dark brown (10YR3/3) silt loam; slightly moist; firm soil strength; semi-deformable failure; moderately plastic; slightly sticky; moderately developed pedality with many medium polyhedral-shaped primary peds; common extremely fine fibrous ubiquitous roots; indistinct boundary.
Bw 37–60 cm	dark brown (10YR3/3) silty clay loam; slightly moist; firm soil strength; semi-deformable failure; plastic; slightly sticky; moderately developed pedality with many medium polyhedral-shaped primary peds; few extremely fine fibrous ubiquitous roots; indistinct boundary.
Cg 60–75 cm	yellowish-brown (10YR5/4) silt loam; dry; abundant 8-mm-diam. distinct (7.5YR6/2) mottles; slightly firm soil strength; semi-deformable failure; moderately plastic; slightly sticky; weakly developed pedality with common medium polyhedral-shaped primary peds; few extremely fine fibrous ubiquitous roots; distinct boundary.
Cg2 75+ cm	light olive grey (2.5Y5/2) sand; dry; no mottles; non-indurated silty textured fluvial parent materials with slight alteration; weak soil strength; brittle failure; non-plastic; non-sticky; undifferentiated, single grained structureless; no boundary observed.

Site WRC01–2 (GW030)

Soil Series	Martinborough loam
Map reference	S27 133 937
GPS coordinates	E2713300 N5990786 (6 m) E2713352 N5990766 (2008)
Location	Martinborough, Pirnoa Road
Transect length and direction °	40 m, 330
Local contact person	Toby Sutherland
Classification	Mottled Immature Pallic Soil
Land use	Dry stock
Date sampled	4 December 2001
Land use history	Long-term pasture
Present vegetation	Rye grass–white clover pasture
Slope °	0
Landform	Terrace
Annual rain (mm)	800
Elevation (m)	24
Parent material	Loess
Drainage	Poorly drained
Topsoil depth (cm)	20
Total rooting depth (cm)	100
Limiting horizon	Poor drainage, firm subsoil
Sampled by	W. Rijkse and P.Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–20	Very dark greyish brown (10YR 3/2) loamy silt; slightly sticky; non-plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; distinct smooth boundary.
Bg1	20–39	Pale olive (5Y 6/3) gritty loamy silt; common medium distinct dark yellowish brown (10YR 4/6) mottles; slightly sticky; slightly plastic; slightly firm soil strength; friable failure; weakly pedal; common fine and very fine roots; indistinct smooth boundary.
Bg2	39–75	Pale olive (5Y 6/3) clay loam; many medium prominent yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; few moderately weathered subrounded gravels (greywacke, 2–5 cm diam.); few fine and very fine roots; indistinct smooth boundary.
Bg3	75–100+	Pale olive (5Y 6/3) clay loam; many medium prominent yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; few fine and very fine roots.

Site WRC01–5 (GW033)

Soil Series	Bideford silt loam
Map reference	S27 006865
GPS coordinates	E2700619 N5986176 (5 m) E2700732 N5986299 (2008)
Location	Martinborough area,
Transect length and direction °	40 m, 40
Local contact person	Brian Weatherstone
Classification	Typic Perch–gley Pallic Soil
Land use	Drystock
Date sampled	4 December 2001
Land use history	Long-term pasture
Present vegetation	Rye grass–white clover pasture
Slope °	0
Landform	Terrace
Annual rain (mm)	1100
Elevation (m)	34
Parent material	Loess
Drainage	Imperfectly drained
Topsoil depth (cm)	22
Total rooting depth (cm)	80
Limiting horizon	Imperfect drainage, firm subsoil
Sampled by	W. Rijkse and P.Cameron (WRC)

Description

Horizon	Depth (cm)	Description
Ap	0–23	Very dark greyish brown (10YR 3/2) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; many fine and very fine roots; indistinct smooth boundary.
AB	23–37	Very dark greyish brown (10YR 3/2) and olive brown (2.5Y 4/4) silt loam; few medium distinct dark yellowish brown (10YR 4/4) mottles; sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; common fine and very fine roots; indistinct smooth boundary
Bw(f)1	37–65	Light olive brown (2.5Y 5/4) silty clay loam; common medium distinct dark yellowish brown (10YR 4/6) mottles; sticky; slightly plastic; slightly firm soil strength; semi-deformable failure; few faint clay coatings; moderately pedal; few fine and very fine roots; indistinct smooth boundary.
Bw(f)2	65–80	Light yellowish brown (2.5Y 6/4) silty clay loam; many medium prominent strong brown (7.5YR 5/8) mottles; sticky; slightly plastic; firm soil strength; deformable failure; massive; few very fine roots; indistinct smooth boundary.
BC	80–100+	Light yellowish brown (2.5Y 6/4) silt loam; common coarse distinct dark yellowish brown (10YR 4/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; massive; no roots.

Site WRC01–9 (GW037)

Soil Series	Tauherenikau silt loam
Map reference	S26 266265
GPS coordinates	E2726794 N6025842 E2726903 N6025889 (2008)
Location	Norfolk Road, west of Wangawa River
Transect length and direction °	40, 35
Local contact person	Alan Williams
Classification	Typic Argillic Pallic Soil
Land use	Drystock
Date sampled	5 December 2001
Land use history	Has been in pasture for 20 years or more
Present vegetation	Rye grass–white clover pasture
Slope	Flat
Landform	Terrace
Annual rain (mm)	1200
Elevation (m)	160
Parent material	Loess
Drainage	Moderately well drained
Topsoil depth (cm)	28
Total rooting depth (cm)	65
Limiting horizon	Stoniness, compact subsoil
Sampled by	W. Rijkse and P. Cameron (WRC)

Description

Horizon	Depth (cm)	Description
Ap	0–28	Very dark brown (10YR 2/2) gravelly silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; strongly pedal; many unweathered rounded greywacke gravels (2–18 cm diam.); abundant fine and very fine roots; sharp smooth boundary.
Bt	28–65	Light olive brown (2.5Y 5/4) gravelly clay loam; sticky; plastic; firm soil strength; friable failure; moderately pedal common distinct dark yellowish brown (10YR 4/4) clay skins; common unweathered rounded greywacke gravels (2–6 cm diam.); few fine and very fine roots; indistinct smooth boundary.
Bw(f)	65–100+	Greyish brown (2.5Y 5/2) clay loam; common medium distinct strong brown (7.5YR 4/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; massive; few unweathered rounded greywacke gravels (2–6 cm diam.); no live roots.

Site WRC 01–15 (GW043)

Soil Series	Manawatu silt loam
Map reference	260 Sheet S25
GPS coordinates	E2692597 N6046941 E2692595 N6046948 (2008)
Location	Grazed strip beside Otaki Race course
Transect length and direction º	40 m, W 290
Local contact person	Paul Denton, WRC
Classification	Mottled Fluvial Recent Soil
Land use	Dry stock
Date sampled	10 April 2002
Land use history	Has had none or little fertiliser in the last 10 years
Present vegetation	Rye grass–white clover pasture
Slope	Flat
Landform	River terrace
Annual rain (mm)	1000
Elevation (m)	8
Parent material	Alluvium derived from greywacke and loess
Drainage	Imperfectly drained
Topsoil depth (cm)	35
Total rooting depth (cm)	120 +
Limiting horizon	None
Sampled by:	W. Rijkse and Paul Denton (WRC)

Description

Horizon	Depth (cm)	Description
Ap	0–20	dark greyish brown (10YR 4/2) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; common very fine and fine roots; diffuse smooth boundary.
A	20–35	dark greyish brown (10YR 4/2) fine sandy loam; slightly sticky; slightly plastic; weak soil strength; friable failure; moderately pedal; common fine and very fine roots; indistinct smooth boundary.
Bw(f)1	35–65	dark greyish brown (2.5Y 4/2) loamy silt; common fine and medium faint dark yellowish brown (10YR 4/6) mottles; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; common very fine and fine roots; distinct smooth boundary.
Bw(f)2	65–80	dark grey (2.5Y 4/1) and grey (10YR 5/1) clay loam; few fine distinct dark yellowish brown (10YR 4/6) mottles; sticky; plastic; slightly firm soil strength; friable failure; massive; few fine and very fine roots; indistinct smooth boundary.
BCr	80–120+	grey (10YR 5/1) clay; sticky; plastic; firm soil strength; deformable failure; massive; few very fine roots.

Site WRC00–22 (GW050)

Soil Series	Rahui silt loam
Map reference	260 Sheet S25
GPS coordinates	E2693026 N6048398 (E2693061 N6048476 (2008)
Location	Along State H'way 1, North of Otaki, opposite Taylor Road junction
Transect length and direction º	40 m, W 260
Local contact person	Paul Denton, WRC
Classification	Acidic Orthic Gley Soil
Land use	Dry stock (deer, beef)
Date sampled	11 April 2002
Land use history	Probably been in pasture for some time
Present vegetation	Rye grass–white clover pasture
Slope	Flat
Landform	Terrace
Annual rain (mm)	1000
Elevation (m)	16
Parent material	Loess derived from greywacke
Drainage	Imperfectly drained
Topsoil depth (cm)	20
Total rooting depth (cm)	68
Limiting horizon	Wet subsoil at 68 cm
Sampled by:	W. Rijkse and Paul Denton (WRC)

Description

Horizon	Depth (cm)	Description
Ap	0–20	Dark brown (10YR 3/3) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; common very fine and fine roots; indistinct smooth boundary.
Bw	20–39	Yellowish brown to light olive brown (10YR to 2.5Y 5/6) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; common fine and very fine roots; distinct smooth boundary.
Bw(f)	39–78	light olive brown (2.5Y 5/4) silty clay loam; common medium distinct dark yellowish brown (10YR 4/6) mottles; sticky; plastic; slightly firm soil strength; semi-deformable failure; massive; few fine and very fine roots; indistinct smooth boundary.
Bg	78–120+	light brownish grey (2.5Y 6/2) silty clay loam; many medium prominent strong brown (7.5YR 5/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; massive; no live roots.

Site: GW03–04 (GW054)

Soil Series	Makara steepland soils
GPS coordinates	E2670325 N6012183 (46 m accuracy) E2670159 N6012515 (2008)
Location	Hill Rd
Transect length and direction °	40 m, 280°
Local contact person	Jim Glover, Hill Road, RD1 Porirua
Classification	Typic Orthic Brown Soils
Land use	Drystock farming
Date sampled	21 October 2003
Land use history	Long-term pasture, gets little superphospate annually
Present vegetation	Pasture
Slope °	35
Landform	Convex steep midslope with terracettes
Annual rain (mm)	1214
Elevation (m)	120
Parent material	Sandstone
Erosion	Moderate creep (no active slips)
Drainage	Well drained
Topsoil depth (cm)	7
Total rooting depth (cm)	120+
Limiting horizon	None
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
Ah	0–7	Dark brown (10YR 3/3) silt loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; distinct wavy boundary.
Bw	7–23	Yellowish brown (10YR 5/6) and dark brown (10YR 3/3) worm clasts; clay loam; sticky; plastic; slightly firm soil strength; friable failure; weakly pedal; few strongly weathered 4–5 mm subangular gravels; common fine and very fine roots; distinct smooth boundary.
BC1	23–70	Brownish yellow (10YR 6/6) clay loam; sticky; plastic; slightly firm soil strength; deformable failure; weakly pedal; few fine and very fine roots; distinct wavy boundary.
BC2	70–120+	Light olive brown (2.5Y 5/4) clay loam; few medium prominent strong brown (7.5 YR 5/6) mottles; sticky; plastic; slightly firm soil strength; massive; few very fine roots.

Site: GW03–06 (GW056)

Soil Series	Korokoro hill soils
GPS coordinates	E2671040 N 6018142 (5 m accuracy) E2671078 N6018154 (2008)
Location	Hill Road
Transect length and direction °	40 m, 270
Local contact person	G.H. Smith, Hill Rd, RD1, Porirua
Classification	Typic Firm Brown Soils
Land use	Dry Stock
Date sampled	21 October 2003
Land use history	Pasture for at least 30 years, some superphospate once a year
Present vegetation	Pasture
Slope °	22
Landform	Convex hilly midslope with terracettes
Annual rain (mm)	1486
Elevation (m)	320
Parent material	Greywacke
Erosion	Moderate creep, very few slips
Drainage	Well drained
Topsoil depth (cm)	15
Total rooting depth (cm)	120+
Limiting horizon	None
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
Ah	0–15	Dark brown (10YR 3/3) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; distinct smooth boundary.
Bw	15–29	Dark yellowish brown (10YR 4/4) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; common fine and very fine roots; indistinct smooth boundary.
Bw	29–60	Light olive brown (2.5Y 5/4) loam; slightly sticky; slightly plastic; slightly firm soil strength; friable failure; weakly pedal; common fine and very fine roots; indistinct wavy boundary.
BC	60–120+	Light olive brown (2.5Y 5/4) clay loam; sticky; plastic; slightly firm soil strength; massive; common moderately weathered angular greywacke gravels (1–6 mm diam); few fine roots.

Site: GW03–08 (GW058)

Soil Series	Paramata hill soil
GPS coordinates	E2669439 N6011400 (6m accuracy) E2669434 N6011401 (2008)
Location	Grey Road, Porirua
Transect length and direction °	40 m, 270
Local contact person	Alan Grey, 325 Grey's Road, Porirua
Classification	Mottled Argillic Pallic Soils
Land use	Drystock
Date sampled	21 October 2003
Land use history	Pasture for at least 30 years, some superphospate once a year
Present vegetation	Pasture
Slope °	23
Landform	Convex hilly midslope with weakly developed terracettes
Annual rain (mm)	1159
Elevation (m)	40
Parent material	Greywacke
Erosion	Slight creep
Drainage	Moderately well drained
Topsoil depth (cm)	12
Total rooting depth (cm)	120+
Limiting horizon	Firm soil strength below 60 cm depth
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–12	Brown (10YR 4/3) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; distinct wavy boundary.
Bt	12–28	Light yellowish brown (12.5Y 6/4) clay loam; sticky; plastic; slightly firm soil strength; friable failure; moderately pedal; common distinct yellowish brown (10YR 5/4) clay coatings on peds; common fine and very fine roots; distinct wavy boundary.
Bg	28–60	Light olive brown (2.5Y 5/4) clay loam; common medium distinct yellowish brown (10YR 5/6) mottles; sticky; plastic; slightly firm soil strength; deformable failure; weakly pedal; few fine and very fine roots; indistinct wavy boundary.
BCg	60–120+	Light brownish grey (2.5Y 6/2) clay; common medium prominent yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; massive; few fine roots.

Site: GW03–10 (GW060)

Soil Series	Tairawhiti steepland soils
GPS coordinates	E2665620 N6015747 (5 m accuracy) E2665887 N6015846 (2008)
Location	North of Plummerton, north of Hongoeka Bay, north of Quarry.
Transect length and direction °	40 m, 320
Local contact person	John Carrad, Plimmerton
Classification	Weathered Orthic Recent Soil
Land use	Drystock
Date sampled	22 October 2003
Land use history	Pasture for at least 25 years, light annual topdressing with superphospate
Present vegetation	Pasture
Slope °	40
Landform	Concavo–convex upper midslope with terracettes and forest dimples
Annual rain (mm)	1269
Elevation (m)	236
Parent material	Greywacke
Erosion	Moderate to severe scree and creep
Drainage	Well drained
Topsoil depth (cm)	14
Total rooting depth (cm)	90
Limiting horizon	Stonniness
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
A	0–14	Dark brown (10YR 3/3) sandy loam; slightly sticky; non-plastic; weak soil strength; friable failure; earthy; few weakly weathered angular greywacke gravels and stones (5–30 mm diam.); many fine and very fine roots; indistinct wavy boundary.
Bw	14–30	Olive brown (2.5Y 4/4) sandy loam; slightly sticky; non–plastic; weak soil strength; friable failure; weakly pedal; few weakly weathered angular greywacke gravels and stones (5–30 mm diam.); common fine and very fine roots; indistinct smooth boundary.
BC1	30–60	Light olive brown (2.5Y 5/4) loamy sand; non-sticky; non-plastic; weak soil strength; friable failure; massive; few fine and medium roots; diffuse wavy boundary.
BC2	60–90	Light olive brown (2.5Y 5/4) sand; non-sticky; non-plastic; weak soil strength; friable failure; single grain; few fine and medium roots; diffuse wavy boundary.
C	90–120+	Greywacke gravels and some light olive brown (2.5Y 5/4) sand.

Site: GW03–11 (GW061)

Soil Series	Tinui hill soils
GPS coordinates	E2738767 N6014848 (4 m accuracy) E2739146 N6014696 (2008)
Location	Te Awa Road, east of Masterton
Transect length and direction °	40 m, 270
Local contact person	A. Buchanon, RD4, Masterton
Classification	Mottled Orthic Brown Soils
Land use	Drystock
Date sampled	22 October 2003
Land use history	Pasture for atleast 30 years, moderate topdressing with superphospate and sulphur
Present vegetation	Pasture
Slope °	22
Landform	Convex hilly midslope with weakly developed terracettes
Annual rain (mm)	1016
Elevation (m)	221
Parent material	Siltstone
Erosion	Moderate creep, moderate to severe slipping
Drainage	Moderately well drained
Topsoil depth (cm)	16
Total rooting depth (cm)	120+
Limiting horizon	Firm soil strength below 29 cm depth
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–16	Very dark greyish brown (10YR 3/2) silt loam; sticky; slightly plastic; slightly firm soil strength; friable failure; strongly pedal; many fine and very fine roots; indistinct wavy boundary.
Bt	16–29	Olive brown (2.5Y 4/4) clay loam; sticky; plastic; slightly firm soil strength; friable failure; strongly pedal; common faint yellowish brown (10YR 5/4) clay coatings on peds; common fine and very fine roots; indistinct wavy boundary.
Bg	29–72	Light yellowish brown (2.5Y 6/4) clay; common fine and medium distinct dark yellowish brown (10YR 4/6) mottles; sticky; plastic; firm soil strength; deformable failure; moderately pedal; few fine and very fine roots; indistinct wavy boundary.
BCg	72–120+	Greyish brown (2.5Y 5/2) clay; common fine distinct yellowish brown (10YR 4/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; few very fine roots.

Site: GW03–16 (GW066)

Soil Series	Wharekaka hill soils
GPS coordinates	E2744083 N6018286 (3 m accuracy) E2743582 N6018712 (2008)*
Location	Patucawa Road, east of Masterton. Site 200 m south of site 15
Transect length and direction °	40 m, 210
Local contact person	Ray Hunter, Patucawa Road, RD 10, Masterton
Classification	Mottled Argillic Pallic Soils
Land use	Dry stock
Date sampled	22 October 2003
Land use history	Pasture for a long time, not topdressed for some time
Present vegetation	Pasture, many thistle
Slope °	24
Landform	Concave–convex hilly midslope with moderately developed terracettes
Annual rain (mm)	995
Elevation (m)	172
Parent material	Mudstone
Erosion	Moderate creep and slip
Drainage	Moderately well drained
Topsoil depth (cm)	14
Total rooting depth (cm)	85
Limiting horizon	Firm soil strength in the subsoil
Sampled by	W. Rijkse and P. Cameron (WRC)

*GWRC Indicated that the resampled location of this site was likely to be significantly off from the original location.

Description:

Horizon	Depth (cm)	Description
Ap	0–14	Dark brown (10YR 3/3) clay loam; sticky; plastic; weak soil strength; friable failure; moderately pedal; abundant fine and very fine roots; distinct wavy boundary.
Bt	14–52	Light yellowish brown (2.5Y 6/4) clay loam; sticky; plastic; slightly firm soil strength; friable failure; moderately pedal; common distinct greyish brown (2.5Y 5/2) clay coatings; many fine and very fine roots; distinct wavy boundary.
Bg1	52–85	Olive grey (5Y 5/2) clay; common fine distinct yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; moderately pedal; few very fine roots; indistinct wavy boundary.
Bg2	85–120+	Olive grey (5Y 5/2) clay; common medium distinct yellowish brown (10YR 5/6) mottles; sticky; plastic; firm soil strength; deformable failure; massive; no live roots.

Site: GW03–18 (GW068)

Soil Series	Wharoama steepland soils
GPS coordinates	E2758314 N6029545 E2758353 N6029386 (2008)
Location	Glen Tarrn, east of Masterton
Transect length and direction °	40 m, 300
Local contact person	P.W. Groves, Glen Tarn, RD9, Masterton
Classification	Weathered Orthic Recent Soils
Land use	Dry Stock
Date sampled	23 October 2003
Land use history	Pasture for 20–30 years, moderate annual superphosphate topdressing
Present vegetation	Pasture
Slope °	35
Landform	Concave midslope with moderately developed terracettes
Annual rain (mm)	1183
Elevation (m)	240
Parent material	Sandstone
Erosion	Moderate creep, many old slips
Drainage	Well drained
Topsoil depth (cm)	13
Total rooting depth (cm)	50
Limiting horizon	Sandston
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
A	0–13	Very dark greyish brown (10YR 3/2) sandy loam; sticky; non-plastic; weak soil strength; friable failure; earthy; abundant fine and medium roots; indistinct wavy boundary.
Bw	13–32	Very dark greyish brown (2.5Y 3/2) and dark greyish brown (2.5Y 4/2) sandy loam; slightly sticky; non-plastic; slightly firm soil strength; friable failure; weakly pedal; common weakly weathered subangular sandstone gravels and stones (2–3 cm diam.); few fine and medium roots; indistinct wavy boundary.
BC	32–50	Light yellow brown (2.5Y 6/4) sandy clay loam; sticky; plastic; firm soil strength; semi-deformable failure; massive; common weakly weathered subangular sandstone gravels and stones (2–3 cm diam.); few fine and very fine roots; indistinct wavy boundary.
C	50+	Light olive brown (2.5Y 5/4) weakly weathered sandstone.

Site: GW03–20 (GW070)

Soil Series	Taihape steepland soils
GPS coordinates	E2761324 N6029092 (6 m accuracy) E2761330 N6029062 (2008)
Location	Ngatoka, east of Masterton
Transect length and direction °	40 m, 300
Local contact person	D. Meredith, Ngatoka, RD 9, Masterton
Classification	Weathered Orthic Recent Soil
Land use	Dry stock
Date sampled	23 October 2003
Land use history	Pasture for 20–30 years, receive maintenance topdressing with superphospate
Present vegetation	Pasture
Slope °	38
Landform	Concave–convex hilly midslope with strongly developed terracettes
Annual rain (mm)	1100
Elevation (m)	157
Parent material	Hard fine sandstone (Taihape series normally on siltstone)
Erosion	Severe, slip, creep and slump
Drainage	Well drained
Topsoil depth (cm)	7
Total rooting depth (cm)	30
Limiting horizon	Firm subsoil
Sampled by	W. Rijkse and P. Cameron (WRC)

Description:

Horizon	Depth (cm)	Description
A	0–7	Dark brown (10YR 3/3) loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; abundant fine and very fine roots; indistinct wavy boundary.
BC	7–26	Olive brown (2.5Y 4/4) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; common fine and medium roots; distinct wavy boundary.
BCg	26–30	Light olive brown (2.5Y 5/4) sandy clay loam; common medium distinct strong brown (7.5YR 4/3) mottles; sticky; plastic; slightly firm soil strength; semi-deformable failure; massive; few very fine roots; diffuse wavy boundary.
C	30–80+	Light olive brown (2.5Y 5/4) sandy loam; slightly sticky; non-plastic; firm soil strength; brittle failure; many strongly weathered subangular sandstone gravels (1 to 3 mm diam); no live roots.

Site: GW05–01 (GW095)

Soil Series	Greytown silt loam
GPS coordinates	E2733206 N6026599 E2733243 N6026614
Location	Masterton Bypass Road, North of Masterton, behind substation opposite Akura Nursery
Transect length and direction °	40 m, S200
Local contact person	David Bulman, Masterton
Classification	Weathered Fluvial Recent Soil
Land use	Drystock
Date sampled	18 October 2004
Land use history	In pasture for a long time
Present vegetation	Pasture
Slope °	0
Landform	River terrace
Annual rain (mm)	1000
Elevation (m)	118
Parent material	Alluvium
Erosion	None
Drainage	Well drained
Topsoil depth (cm)	29
Total rooting depth (cm)	120
Limiting horizon	None
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–29	Very dark grey (10YR 3/1) silt loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; common fine and very fine roots; distinct smooth boundary.
BC1	29–55	Greyish brown (10YR 5/2) silt loam; sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; few fine and very fine roots; distinct smooth boundary.
BC2	55–120+	Greyish brown (2.5Y 5/2) sandy loam; slightly sticky; non-plastic; weak soil strength; friable failure; massive; few very fine roots.

Site: GW05–05 (GW099)

Soil Series	Kokotau silt loam
GPS coordinates	E2738068 N6024377 E2738068 N6024391 (2008)
Location	Mangahuia; Castlepoint Road
Transect length and direction °	40 m, E 120
Local contact person	Bruce McKenzie
Classification	Mottled Immature Pallic Soil
Land use	Drystock
Date sampled	19 October 2004
Land use history	Superphosphate maintenance topdressing
Present vegetation	Rye grass/white clover pasture
Slope °	0
Landform	Terrace
Annual rain (mm)	1000
Elevation (m)	97
Parent material	Loess
Erosion	None
Drainage	Moderately well drained
Topsoil depth (cm)	22
Total rooting depth (cm)	120
Limiting horizon	None
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–22	Dark greyish brown (10YR 4/2) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; moderately pedal; many fine and very fine roots; indistinct smooth boundary.
Bg	22–60	Olive brown (2.5Y 4/4) clay loam; common fine faint yellowish brown (10YR 5/4 and prominent strong brown (7.5YR 5/8) mottles; slightly sticky; slightly plastic; weak soil strength; friable failure; moderately to weakly pedal; common fine and very fine roots; indistinct wavy boundary.
BC	60–100+	Light olive brown (2.5Y 5/4) loamy sand; non-sticky; non-plastic; weak soil strength; friable failure; massive; few very fine roots.

Site: GW05–12 (GW106)

Soil Series	Greytown silt loam
GPS coordinates	E2711785 N5994702 E2700731 N5986331 (2008)
Location	Mahaki Road, west of Martinborough, on Ruamahanga River flats
Transect length and direction °	40 m, NE 40
Local contact person	Tim Walls
Classification	Weathered Orthic Recent Soil
Land use	Dry stock
Date sampled	19 October 2004
Land use history	Long-time/term pasture, maintenance superphosphate
Present vegetation	Rye grass and some white clover pasture
Slope °	0
Landform	River terrace
Annual rain (mm)	800
Elevation (m)	13
Parent material	Alluvium
Erosion	None
Drainage	Well drained
Topsoil depth (cm)	26
Total rooting depth (cm)	120
Limiting horizon	None
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–26	Dark greyish brown (2.5Y 4/2) silt loam; sticky; slightly plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; indistinct smooth boundary.
Bw	26–70	Dark greyish brown to greyish brown (2.5Y 4/2–5/2) silt loam; sticky; plastic; weak soil strength; friable failure; weakly pedal; common fine and very fine roots; distinct smooth boundary.
BCg1	70–90	Dark greyish brown (2.5Y 4/2) silt loam; common medium distinct dark yellowish brown (10YR 4/6) mottles; sticky; slightly plastic; slightly firm soil strength; friable failure; weakly pedal; few fine and very fine roots; indistinct smooth boundary.
BCg2	90–120+	Dark greyish brown (2.5Y 4/2) silt loam; common medium distinct strong brown (7.5YR 4/6) mottles; sticky; slightly plastic; weak soil strength; friable failure; massive; few very fine roots.

Site: GW05–20 (GW114)

Soil Series	Shannon silt loam
GPS coordinates	E2695865 N6049918 E2695857 N6049924 (2008)
Location	Along eastern side of State Highway 1, North of Otaki
Transect length and direction °	40 m. N10
Local contact person	Dave Gault
Classification	Mottled Immature Pallic Soil
Land use	Dry stock
Date sampled	20 October 2004
Land use history	Maintenance phosphate
Present vegetation	Pasture
Slope °	0
Landform	Terrace
Annual rain (mm)	1000
Elevation (m)	60
Parent material	Loess
Erosion	None
Drainage	Imperfectly drained
Topsoil depth (cm)	20
Total rooting depth (cm)	120+
Limiting horizon	Imperfect natural drainage
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–20	Dark greyish brown (10YR 4/2) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; many fine and very fine roots; distinct smooth boundary.
Bw1	20–51	Light olive brown (2.5Y 5/4) silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; few fine and very fine roots; indistinct smooth boundary.
Bg	51–120+	Greyish brown (2.5Y 5/2) clay loam; sticky; plastic; slightly firm soil strength; semi-deformable failure; weakly pedal; few fine and very fine roots.

Site: GW05–24 (GW118)

Soil Series	Te Horo stony silt loam
GPS coordinates	E2689547 N6043562 E2689520 N6043594
Location	North of Te Horo, eastern side of State Highway 1. Site parallel to the State Highway and railway
Transect length and direction °	40 m, N 20
Local contact person	John Winiata
Classification	Typic Orthic Brown Soil
Land use	Drystock
Date sampled	21 October 2004
Land use history	Has been in pasture for a long time, superphosphate topdressing
Present vegetation	Pasture
Slope °	0
Landform	Terrace
Annual rain (mm)	1000
Elevation (m)	18
Parent material	Loess and alluvial gravels
Erosion	None
Drainage	Well drained
Topsoil depth (cm)	22
Total rooting depth (cm)	65+
Limiting horizon	Stoniness
Sampled by	W. Rijkse and B. Croucher (WRC)

Description:

Horizon	Depth (cm)	Description
Ap	0–22	Very dark greyish brown (10YR 3/2) stony silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; earthy; abundant unweathered rounded gravels, stones and boulders; abundant fine and very fine roots; distinct wavy boundary.
Bw1	22–65	Olive brown (2.5Y 4/4)) stony silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; abundant unweathered rounded gravels and stones; common fine and very fine roots; indistinct wavy boundary.
Bw2	65+	Olive brown (2.5Y 4/4)) stony silt loam; slightly sticky; slightly plastic; weak soil strength; friable failure; weakly pedal; many unweathered rounded gravels and stones; few fine and very fine roots.

Table showing all current, biochemical and physical data on a volume basis for drystock sites sampled in 2008

GWRC Code	LCR Code	pH	TC mg/cm^3	TN mg/cm^3	C:N ratio	AMN $\mu g/cm^3$	Olsen P $\mu g/cm^3$	Bd Mg/m^3	Pd Mg/m^3	Macro Porosity (–5kPa) %v/v	Tpor %v/v
		Current (2007) Measurements									
GW002	WRC00_02	5.3	88.1	7.6	11.5	160	96	0.99	2.37	10.2	58.4
GW008	WRC00_08	6.2	51.4	4.7	10.9	133	33	1.08	2.52	11.9	57.3
GW012	WRC00_12	5.8	46.4	3.9	12.0	125	11	1.24	2.62	13.4	52.7
GW018	WRC00_18	5.9	42.6	3.7	11.5	123	32	1.28	2.62	6.2	51.3
GW026	WRC00_26	5.8	51.2	4.8	10.7	182	74	1.23	2.63	8.6	53.4
GW030	WRC01_02	6.0	43.1	4.1	10.5	142	43	1.24	2.60	11.4	52.6
GW033	WRC01_05	5.1	50.0	4.7	10.6	124	53	1.29	2.57	7.3	49.9
GW037	WRC01_09	5.8	84.8	6.7	12.6	136	23	0.77	2.40	21.8	67.9
GW043	WRC01_15	5.7	51.5	5.0	10.4	172	56	1.19	2.60	5.6	54.3
GW050	WRC01_22	6.0	48.8	4.4	11.0	153	8	0.97	2.54	6.6	61.6
GW054	GW03-04	6.5	50.5	4.3	11.6	114	12	0.97	2.51	14.0	61.1
GW056	GW03-06	5.6	61.3	5.1	12.1	144	9	0.91	2.45	15.5	62.7
GW058	GW03-08	5.3	54.6	4.7	11.7	143	26	1.22	2.53	10.0	51.8
GW060	GW03-10	5.7	40.2	3.6	11.3	126	22	1.13	2.56	15.1	56.0
GW061	GW03-11	5.2	84.4	7.8	10.8	252	45	0.98	2.46	13.2	60.2
GW066	GW03-16	6.1	41.2	3.8	10.9	91	14	1.10	2.57	13.8	57.1
GW068	GW03-18	5.9	55.9	5.6	10.0	160	22	1.03	2.50	12.7	58.7
GW070	GW03-20	6.0	43.9	3.6	12.1	150	36	1.25	2.59	8.1	51.8
GW095	GW05-01	6.1	62.1	5.8	10.8	188	110	1.29	2.61	6.7	50.5
GW099	GW05-05	6.9	58.0	5.8	10.0	158	134	1.15	2.56	5.3	55.2
GW106	GW05-12	6.1	47.8	5.0	9.6	215	72	1.33	2.63	7.7	49.5
GW114	GW05-20	6.2	60.9	6.0	10.1	152	52	1.18	2.54	2.2	53.6
GW118	GW05-24	5.7	85.9	7.5	11.5	146	40	0.92	2.39	13.5	61.5

Table showing all previous chemical, biochemical and physical data on a volume basis for drystock sites resampled in 2008

GWRC Code	LCR Code	pH	TC mg/cm^3	TN mg/cm^3	C:N ratio	AMN $\mu g/cm^3$	Olsen P $\mu g/cm^3$	Bd Mg/m^3	Pd Mg/m^3	Macro Porosity (–5kPa) %v/v	Tpor %v/v
		Previous Sampling									
GW002	WRC00_02	5.27	82.9	6.98	11.9	198	69	0.92	2.4	11.4	61.9
GW008	WRC00_08	5.36	46.3	4.23	10.9	149	22	1.1	2.5	7.9	56.1
GW012	WRC00_12	5.42	39.8	3.2	12.4	105	8	0.96	2.5	24.9	61.7
GW018	WRC00_18	5.54	39.6	3.32	11.9	100	14	1.3	2.6	5.6	50.1
GW026	WRC00_26	6.01	47.2	3.88	12.2	182	30	1.29	2.62	6.3	51.5
GW030	WRC01_02	5.85	43.7	3.78	11.6	108	12.8	1.13	2.53	5.7	55.2
GW033	WRC01_05	5.6	36.5	3.07	11.9	102	36.6	1.15	2.55	4.2	54.7
GW037	WRC01_09	5.64	56.7	4.96	11.4	137	16.1	0.82	2.4	11.5	65.8
GW043	WRC01_15	5.58	48.5	4.32	11.2	211	57.5	1.16	2.61	6.7	55.5
GW050	WRC01_22	6.83	63	5.54	11.4	419	32.8	1.07	2.55	17.8	58.5
GW054	GW03-04	5.14	56.7	3.8	14.9	76	10	1.23	2.53	3.6	51.4
GW056	GW03-06	5.27	59.1	4.6	12.8	91	7.3	0.87	2.48	10.4	64.8
GW058	GW03-08	5.37	49.1	4	12.3	91	24	1.08	2.54	9.4	57.6
GW060	GW03-10	5.51	35.9	2.8	12.8	80	14.4	1.1	2.64	25	58.3
GW061	GW03-11	5.35	60	5.2	11.5	115	17.5	1.12	2.61	15.5	57
GW066	GW03-16	5.82	57.7	5.5	10.5	112	10.1	1.28	2.64	5.8	51.3
GW068	GW03-18	5.53	43.8	3.8	11.5	99	13.8	1.16	2.56	11.2	54.6
GW070	GW03-20	5.51	39.9	3.2	12.5	100	27.4	1.24	2.58	12.4	52.1
GW095	GW05-01	6.06	37.9	3.7	10.3	135	65.2	1.19	2.61	2.5	54.4
GW099	GW05-05	6.49	40.6	3.9	10.5	104	60.6	1.24	2.60	1.0	53.0
GW106	GW05-12	6.13	36.3	3.7	9.9	124	49.3	1.38	2.65	3.6	48.7
GW114	GW05-20	6.22	45.3	4.2	10.9	98	24.7	1.04	2.53	3.1	58.9
GW118	GW05-24	5.16	89.9	7.7	11.7	164	67.1	1.01	2.41	3.6	58.1

Table showing all current (2008) chemical data (mass basis)

Soil Analysis Results

Environmental Chemistry Laboratory

Manaaki Whenua
Landcare Research

Client: Bryan Stevenson, Landcare Research **Date In:** 1st May 2008

Job No.: LJ07168 **Date Out:** 4th June 2008

Client ID	Sample No.	pH (water) (method 106)	Total C (method 114) (%)	Total N (method 114) (%)	KCl-extractable NO3-N (method 118) (mg/kg)	KCl-extractable NH4-N (method 118) (mg/kg)	Anaerobic Mineralisable-N (method (120) (mg/kg)	Olsen P (method 124) (mg/kg)
GW002	M7/7739	5.33	8.94	0.77	78.3	6.41	162	97
GW008	M7/7740	6.22	4.77	0.44	61.6	0.46	124	31
GW012	M7/7741	5.77	3.73	0.31	15.5	1.79	100	9
GW018	M7/7742	5.92	3.34	0.29	16.1	1.19	96	25
GW026	M7/7743	5.77	4.17	0.39	61.4	1.39	148	60
GW030	M7/7744	6.02	3.49	0.33	43.8	3.94	115	35
GW033	M7/7745	5.14	3.88	0.37	71.0	2.57	96	41
GW037	M7/7746	5.78	11.0	0.87	70.0	5.65	176	30
GW043	M7/7747	5.68	4.34	0.42	43.1	0.53	145	48
GW050	M7/7748	5.98	5.01	0.45	32.4	0.73	157	9
GW054	M7/7749	6.50	5.18	0.45	58.9	0.36	117	12
GW056	M7/7750	5.60	6.71	0.55	22.8	2.74	157	10
GW058	M7/7751	5.34	4.47	0.38	35.4	4.72	117	21
GW060	M7/7752	5.69	3.57	0.32	32.8	12.3	112	19
GW061	M7/7753	5.24	8.60	0.80	108	17.3	257	46
GW066	M7/7754	6.08	3.73	0.34	24.2	0.34	83	13
GW068	M7/7755	5.94	5.41	0.54	48.3	0.77	155	22
GW070	M7/7756	6.03	3.52	0.29	16.6	0.33	120	28
GW095	M7/7757	6.14	4.81	0.45	61.5	2.01	145	85
GW099	M7/7758	6.94	5.06	0.51	122	0.44	138	117
GW106	M7/7759	6.09	3.60	0.37	138	0.29	162	54
GW114	M7/7760	6.23	5.17	0.51	64.9	0.37	129	45
GW118	M7/7761	5.71	9.32	0.81	73.1	1.56	159	44

Table showing full current (2008) soil physical data (3 replicates)

Greater Wellington Soil Quality 2008
Moisture Release Results
Job Code: 682 202 0027
June 2008

Lab Number	Client ID	Initial Water Content	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air Filled Porosity	Vol. WC 5kPa	Vol. WC 10kPa
		(%, w/w)	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
HP3592a	GW070	19.9	1.11	2.58	57.0	12.8	15.2	44.3	41.8
HP3592b		24.5	1.10	2.55	56.8	8.5	10.8	48.3	46.0
HP3592c		19.0	1.54	2.64	41.6	3.1	4.4	38.5	37.2
HP3593a	GW068	35.5	1.00	2.47	59.4	11.4	13.7	47.9	45.7
HP3593b		35.1	0.95	2.49	61.8	15.3	17.8	46.4	44.0
HP3593c		21.4	1.15	2.54	54.8	11.3	12.4	43.5	42.4
HP3594a	GW026	23.0	1.27	2.62	51.7	6.0	8.1	45.7	43.6
HP3594b		22.7	1.18	2.63	55.1	10.0	12.5	45.1	42.6
HP3594c		23.2	1.24	2.65	53.4	9.8	12.1	43.5	41.3
HP3595a	GW095	26.1	1.22	2.57	52.5	6.6	8.7	45.8	43.8
HP3595b		21.4	1.33	2.61	48.9	6.5	8.6	42.3	40.3
HP3595c		19.3	1.32	2.64	50.1	7.0	8.4	43.1	41.7
HP3596a	GW066	25.9	1.08	2.57	58.2	13.5	16.7	44.7	41.5
HP3596b		21.8	1.09	2.58	57.6	14.0	16.5	43.6	41.1
HP3596c		18.7	1.15	2.57	55.4	13.8	16.3	41.5	39.1
HP3597a	GW061	35.5	0.95	2.46	61.5	12.9	14.8	48.6	46.7
HP3597b		25.6	0.99	2.49	60.2	13.2	14.9	47.0	45.3
HP3597c		18.5	1.01	2.45	58.8	13.4	15.3	45.4	43.5
HP3598a	GW099	30.7	1.16	2.55	54.5	4.9	7.6	49.6	46.9
HP3598b		37.2	1.22	2.55	52.1	2.7	3.2	49.4	48.9
HP3598c		44.5	1.06	2.58	59.0	8.3	10.3	50.6	48.7
HP3599a	GW037	53.8	0.71	2.40	70.6	25.3	29.4	45.2	41.2
HP3599b		48.6	0.83	2.38	65.3	16.6	19.7	48.7	45.6
HP3599c		45.4	0.78	2.42	67.8	23.6	27.2	44.3	40.6
HP3600a	GW033	27.9	1.19	2.55	53.3	8.3	10.6	45.0	42.7
HP3600b		22.0	1.29	2.59	50.1	7.1	10.5	43.0	39.6
HP3600c		20.6	1.39	2.57	46.2	6.4	8.0	39.8	38.2
HP3601a	GW106	19.1	1.39	2.64	47.4	4.9	6.3	42.5	41.1
HP3601b		18.7	1.36	2.63	48.3	7.8	8.7	40.6	39.6
HP3601c		21.2	1.24	2.63	52.9	10.5	12.3	42.3	40.6
HP3602a	GW114	38.1	1.15	2.53	54.4	1.7	4.2	52.8	50.2
HP3602b		37.8	1.18	2.53	53.5	2.5	4.3	51.0	49.2
HP3602c		35.6	1.21	2.56	52.8	2.4	5.5	50.4	47.3
HP3603a	GW050	48.8	1.03	2.53	59.3	4.6	7.7	54.7	51.6
HP3603b		57.4	0.91	2.54	64.3	6.6	10.6	57.8	53.7
HP3603c		50.9	0.99	2.56	61.3	8.6	11.6	52.7	49.7
HP3604a	GW043	34.9	1.17	2.58	54.5	5.7	8.0	48.8	46.5
HP3604b		36.4	1.18	2.61	54.8	5.3	7.9	49.5	46.9
HP3604c		33.6	1.21	2.61	53.7	5.8	8.5	47.9	45.2
HP3605a	GW012	22.1	1.37	2.68	49.1	11.3	13.1	37.8	36.0
HP3605b		30.7	1.09	2.60	57.9	14.2	18.6	43.6	39.3
HP3605c		21.8	1.27	2.60	51.1	14.8	17.4	36.2	33.7
HP3606a	GW060	24.1	1.12	2.54	55.7	15.6	22.8	40.1	32.9
HP3606b		21.3	1.14	2.56	55.4	13.9	20.6	41.5	34.8
HP3606c		26.9	1.11	2.59	57.0	15.8	22.5	41.2	34.5
HP3607a	GW002	30.9	1.05	2.42	56.5	11.5	15.8	45.1	40.7
HP3607b		45.1	0.89	2.31	61.5	9.6	14.6	51.9	46.9
HP3607c		34.6	1.02	2.39	57.3	9.5	13.6	47.9	43.7
HP3608a	GW0056	34.2	0.85	2.38	64.3	12.8	17.8	51.5	46.5
HP3608b		30.2	0.95	2.50	61.8	17.1	19.7	44.8	42.1
HP3608c		25.1	0.94	2.47	62.1	16.5	19.4	45.6	42.7
HP3609a	GW054	34.5	1.00	2.55	60.7	12.2	16.8	48.5	43.9
HP3609b		41.5	0.94	2.47	61.7	15.9	18.4	45.9	43.3
HP3609c		37.7	0.98	2.51	61.0	14.0	16.4	47.0	44.6
HP3610a	GW058	23.5	1.26	2.55	50.8	9.8	11.6	41.0	39.2
HP3610b		14.7	1.22	2.53	51.7	10.5	12.3	41.2	39.4
HP3610c		28.7	1.18	2.51	53.0	9.7	12.0	43.3	41.0
HP3611a	GW118	41.0	0.92	2.37	61.1	11.9	16.6	49.2	44.5
HP3611b		36.6	0.97	2.47	60.9	13.6	17.7	47.2	43.2
HP3611c		38.9	0.88	2.35	62.6	15.1	20.0	47.5	42.6
HP3612a	GW008	37.0	1.06	2.52	57.8	13.6	15.8	44.2	42.0
HP3612b		36.1	1.08	2.53	57.2	10.4	12.6	46.8	44.6
HP3612c		33.6	1.08	2.52	56.9	11.7	14.5	45.2	42.4
HP3613a	GW018	30.5	1.30	2.60	50.2	5.7	8.0	44.5	42.2
HP3613b		32.7	1.27	2.62	51.4	5.3	7.5	46.0	43.9
HP3613c		32.3	1.26	2.64	52.3	7.6	10.1	44.7	42.2
HP3614a	GW030	28.4	1.20	2.60	53.9	12.4	14.7	41.5	39.2
HP3614b		25.9	1.33	2.64	49.5	9.4	11.3	40.0	38.2
HP3614c		28.2	1.17	2.57	54.4	12.3	15.2	42.0	39.2

Notes: GW070 (HP3592c) was a different colour and texture relative to its replicates.
GW099 (HP3598b) was a different colour relative to its replicates

Analyst: DT

Current (2008) soil total recoverable metals data (from Hill Laboratories, provided to LCR by GWRC)

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ANALYSIS REPORT

Client:	Greater Wellington	Lab No:	637542	SPv1
Contact:	Sorenson, Paul	Date Registered:	08-Apr-2008	
	c/o Greater Wellington	Date Reported:	11-Apr-2008	
	The Regional Council	Quote No:	31978	
	P O Box 11646	Order No:		
	WELLINGTON	Client Reference:	Metals in Soils	
		Submitted By:	Sorenson, Paul	

Sample Type: Soil

Sample Name:		GW070 02-Apr-2008 10:00 am	GW068 02-Apr-2008 10:30 am	GW026 02-Apr-2008 10:45 am	GW095 02-Apr-2008 11:55 am	GW066 02-Apr-2008 11:40 am
Lab Number:		637542.1	637542.2	637542.3	637542.4	637542.5
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	6.3	6.1	6.3	7.9	23
Total Recoverable Cadmium	mg/kg dry wt	0.12	0.18	0.26	0.15	0.14
Total Recoverable Chromium	mg/kg dry wt	12	12	20	20	11
Total Recoverable Copper	mg/kg dry wt	9.8	12	25	21	11
Total Recoverable Lead	mg/kg dry wt	12	12	24	43	11
Total Recoverable Nickel	mg/kg dry wt	8.6	11	20	20	6.3
Total Recoverable Zinc	mg/kg dry wt	54	67	93	110	51

Sample Name:		GW061 02-Apr-2008 2:00 pm	GW099 03-Apr-2008 11:00 am	GW037 03-Apr-2008 12:10 pm	GW033 03-Apr-2008 1:00 pm	GW106 03-Apr-2008 2:15 pm
Lab Number:		637542.6	637542.7	637542.8	637542.9	637542.10
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	2.6	4.7	3.3	2.7	6.0
Total Recoverable Cadmium	mg/kg dry wt	0.40	0.39	0.45	0.20	0.21
Total Recoverable Chromium	mg/kg dry wt	16	21	12	15	21
Total Recoverable Copper	mg/kg dry wt	8.8	10	8.5	7.6	18
Total Recoverable Lead	mg/kg dry wt	8.1	15	13	9.1	18
Total Recoverable Nickel	mg/kg dry wt	9.7	15	5.3	9.2	21
Total Recoverable Zinc	mg/kg dry wt	62	75	51	51	85

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Samples
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction.	-	1-10
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	-	1-10
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2	-	1-10

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Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

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ANALYSIS REPORT

Client:	Greater Wellington	Lab No:	638488	SPv1
Contact:	Sorenson, Paul	Date Registered:	15-Apr-2008	
	c/o Greater Wellington	Date Reported:	22-Apr-2008	
	The Regional Council	Quote No:	31978	
	P O Box 11646	Order No:		
	WELLINGTON	Client Reference:	Metals in Soils	
		Submitted By:	Sorenson, Paul	

Sample Type: Soil

Sample Name:	GW114 09-Apr-2008 10:00 am	GW050 09-Apr-2008 11:00 am	GW043 09-Apr-2008 12:00 pm	GW012 09-Apr-2008 2:00 pm	GW060 09-Apr-2008 3:30 pm
Lab Number:	638488.1	638488.2	638488.3	638488.4	638488.5
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn					
Total Recoverable Arsenic mg/kg dry wt	3.4	4.8	7.2	8.5	<2.0
Total Recoverable Cadmium mg/kg dry wt	0.55	0.34	<0.10	0.12	<0.10
Total Recoverable Chromium mg/kg dry wt	17	17	17	18	7.6
Total Recoverable Copper mg/kg dry wt	13	13	23	15	3.8
Total Recoverable Lead mg/kg dry wt	9.2	20	25	39	6.6
Total Recoverable Nickel mg/kg dry wt	11	9.5	15	17	4.6
Total Recoverable Zinc mg/kg dry wt	68	58	88	120	32

Sample Name:	GW002 10-Apr-2008 10:00 am	GW056 10-Apr-2008 1:00 pm	GW054 10-Apr-2008 2:00 pm	GW058 10-Apr-2008 3:00 pm	
Lab Number:	638488.6	638488.7	638488.8	638488.9	
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn					
Total Recoverable Arsenic mg/kg dry wt	3.1	3.7	2.3	3.1	-
Total Recoverable Cadmium mg/kg dry wt	0.48	0.16	0.19	0.17	-
Total Recoverable Chromium mg/kg dry wt	12	12	9.4	9.3	-
Total Recoverable Copper mg/kg dry wt	6.4	7.9	5.3	4.7	-
Total Recoverable Lead mg/kg dry wt	9.6	11	6.7	18	-
Total Recoverable Nickel mg/kg dry wt	5.1	7.7	5.6	4.4	-
Total Recoverable Zinc mg/kg dry wt	52	51	31	36	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Samples
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction.	-	1-9
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	-	1-9
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2	-	1-9

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JC Sherrard

Jane Sherrard PhD
Inorganics Section Manager - Environmental Division

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ANALYSIS REPORT

Client:	Greater Wellington	**Lab No:**	639349	SPv1
Contact:	Sorenson, Paul	**Date Registered:**	22-Apr-2008	
	c/o Greater Wellington	**Date Reported:**	02-May-2008	
	The Regional Council	**Quote No:**	31978	
	P O Box 11646	**Order No:**		
	WELLINGTON	**Client Reference:**	Metals in Soils	
		Submitted By:	Sorenson, Paul	

Sample Type: Soil

Sample Name:		GW118 16-Apr-2008 10:30 am	GW008 16-Apr-2008 11:30 am	GW018 21-Apr-2008 11:00 am	GW030 21-Apr-2008 12:30 pm	
Lab Number:		639349.1	639349.2	639349.3	639349.4	
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn						
Total Recoverable Arsenic	mg/kg dry wt	2.7	3.2	3.1	< 2.0	-
Total Recoverable Cadmium	mg/kg dry wt	0.60	0.20	0.19	0.30	-
Total Recoverable Chromium	mg/kg dry wt	9.9	16	15	10	-
Total Recoverable Copper	mg/kg dry wt	8.6	13	8.7	3.0	-
Total Recoverable Lead	mg/kg dry wt	17	14	12	8.8	-
Total Recoverable Nickel	mg/kg dry wt	4.5	10	10	6.3	-
Total Recoverable Zinc	mg/kg dry wt	49	68	61	43	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Samples
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction.	-	1-4
Heavy metal screen level As,Cd,Cr,Cu,Ni,Pb,Zn	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, screen level.	-	1-4
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2	-	1-4

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