



**MARLBOROUGH
DISTRICT COUNCIL**

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Soil Properties in the Havelock/ Kaituna and Linkwater Districts

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Executive Summary

Currently Council has detailed information for soils mapped on the Wairau Plain and the lower Awatere Valley. For the rest of Marlborough we have very little or more often no soils information available. An example is the Kaituna/Havelock district where there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This information is critical if we want to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management etc. Furthermore, a range of models such as OVERSEER, SPASMO and the Dairy Pond Calculator require accurate soils information to help predict things like nutrient losses from soils, water availability and the suitability of soils for effluent application.

Because soils act as buffers to capture and store nutrients and microbes, treat a range of waste products and store and filter water, accurate soils information is critical. Council, industry and landowners require this information to maintain and enhance water quality, accurately allocate/use water and protect our important soil resources.

The aim of this project was therefore to describe and sample soils from representative sites in the Kaituna/Havelock and Linkwater districts and undertake a range of analysis for both topsoil and subsoils. This information will be summarised into fact sheets and made available to landowners in the region and be available for incorporation into various models used by Council and industry to ensure the most efficient use and protection of our natural resources.

A series of soil auger observations were made across a range of sites in the Kaituna/Havelock and Linkwater districts to identify the dominant soil types. Nineteen soil profiles were described and top and subsoils sampled and analysed for a range of soil physical and chemical properties.

Three soil families were identified i.e. Koromiko, Manaroa and Kaituna which occupy different parts of the landscape. The Koromiko family of soils occurs on the lower land surfaces – on stream and river floodplains and low terraces. The Manaroa family occur on surfaces intermediate between the lower floodplains and remnant terrace and fan surface. The Kaituna family occurs on terraces and fans that occur above the valley floor.

All three soils were generally well or moderately well drained, moderately deep to deep, moderate to moderately rapid permeability and have high water storage capacities – although there were some exceptions. These properties make the soils generally 'low risk' in terms of direct losses from land application of effluent because of their ability to store and treat effluent. Detailed, farm scale soil mapping (i.e. 1:5,000) would help separate soils within the families which aren't as well drained or those with lower permeabilities and should be done on a site specific basis when categorising the soil for effluent or irrigation application.

Contents

Executive Summary	i
1. Introduction	1
1.1 Aim.....	1
2. Material and Methods	1
2.1 Sites.....	1
2.2 Soil Sampling	1
2.3 Soil Analyses.....	2
2.3.1 Chemical.....	2
2.3.2 Physical.....	3
3. Results and Discussion	3
3.1 General setting	3
3.2 Previous soil investigations	3
3.3 Soil Characteristics	4
3.4 Koromiko Soil.....	4
3.5 Manaroa Soil.....	6
3.6 Kaituna Soil	8
4. Summary	9
5. References	10
Appendix A	11
Appendix B	16

1. Introduction

Currently Council has detailed information for soils mapped on the Wairau Plain and the lower Awatere Valley. This information has been compiled by Landcare Research into soil fact sheets which summarise key properties (e.g. water holding capacity, soil depth, texture) for a particular soil that can be used to help landowners better manage their soils. For the rest of Marlborough we only have very little or more often no soils information available. An example is the Kaituna/Havelock district where there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This information is critical if we want to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management etc. For example, you need to know how much capacity a soil has to assimilate effluent or irrigation and at what rate you can apply it without it ponding or running offsite. In addition, detailed soil physical information is also central to many models Council and industry use to make decisions on how to manage our natural and physical resources. For example the latest version of the nutrient budget model OVERSEER requires topsoil and subsoil texture information to help predict nutrient (nitrate) losses from soils. The irrigation scheduling tool SPASMO requires a comprehensive set of soil physical and hydraulic properties to calculate a soil water balance including soil texture, bulk density, water holding capacity and drainage class. Likewise the Dairy Pond Calculator being promoted by Dairy NZ and Regional Councils to farmers to help manage dairy effluent application requires information on soils to help determined pond storage requirements.

Because soils act as buffers to capture and store nutrients and microbes, treat a range of waste products and store and filter water, accurate soils information is therefore critical. Council, industry and landowners require this information to maintain and enhance water quality, accurately allocate/use water and protect our important soil resources.

1.1 Aim

The aim of this project is therefore to describe and sample soils from representative sites in the Kaituna/Havelock and Linkwater districts and undertake a range of analysis for both topsoil and subsoils. This information will be summarised into fact sheets and made available to landowners in the region. The information will also be available for incorporation into various models that Council and industry uses to help protect and manage our natural resources.

2. Material and Methods

2.1 Sites

A series of soil auger observations were made across a range of sites in the Kaituna/Havelock and Linkwater districts to identify the dominant soil types. Nineteen soil profiles were described and top and subsoils sampled and analysed for a range of soil physical and chemical properties. When specific soils were identified a soil pit was dug to about 1 m depth and a detailed soil profile description was undertaken to confirm the soil type and to note any salient soil features that may affect soil management i.e. rooting depth, mottling, hardpans etc. In addition, details of the site were recorded such as slope, elevation, landform, parent material and soil drainage class. In total 19 soil pits were sampled in the Kaituna/Havelock and Linkwater districts (Figure 1).

2.2 Soil Sampling

From each pit bulk topsoil and subsoil samples were taken for chemical analysis. In addition duplicate undisturbed soil cores (100 mm diameter by 75 mm depth) were sampled. The soil cores were removed as one unit by excavation around the liner, bagged and loaded into padded crates for transport to the laboratory for analysis. These soil samples were used for soil physical analysis.



Figure 1. Location of soil sampling sites

2.3 Soil Analyses

2.3.1 Chemical

All soil chemical analysis was undertaken by Hills Laboratory, Hamilton. Soil pH was measured in water using glass electrodes and a 2:1 water to soil ratio (Blackmore et al., 1987). Total carbon and nitrogen were determined by dry combustion of air-dry soil using a LECO 2000 CNS analyser (Blakemore et al., 1987). Olsen P was determined by extracting soils for 30 min with 0.5 M NaHCO_3 at pH 8.5 (Olsen, 1954) and measuring the phosphate concentration by the molybdenum blue method. Exchangeable cations i.e. Ca, Mg, K and Na were determined by extraction in ammonium acetate at pH 7 and analysed by ICP-OES. Anion storage capacity (Phosphate retention) was determined by equilibrium with 0.02 M potassium phosphate and analysis by ICP-OES. Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in $\text{NH}_4\text{-N}$ concentration was measured after incubation for 7 days at 40 °C and extraction in 2 M KCl (Keeney and Bremner, 1966). Trace element concentrations in soils i.e. total recoverable copper, chromium, cadmium, arsenic, mercury, lead, nickel and zinc were determined by digesting soils in nitric/hydrochloric acid and analysing trace elements in the digest by inductively coupled plasma mass spectrometry (US EPA 200.2).

2.3.2 Physical

Soil physical analysis was undertaken by Landcare Research in Hamilton. Dry bulk density was measured on undisturbed soil cores dried in an oven at 105°C until the weight remained constant and the sample was then weighed (Gradwell and Birrell, 1979). Particle density was measured by the pipette method. Soil water moisture content was determined at -5, -10, -100 and -1500 kPa tensions. This data was used to calculate Total Available Water (TAW) at the 0-30mm and 0-60mm soil depth. Total Available Water is the amount of water (in mm) that can be extracted between field capacity (-10kPa suction) and permanent wilting point (-1500 kPa). Total available water is effectively a measure of the amount of water storage there is in a soil. The capacity is affected by a range of soil properties including soil texture, structure, organic matter content, soil depth, profile layer and stone content.

3. Results and Discussion

3.1 General setting

The soils on the low surfaces of the valleys in the Kaituna/Havelock and the Linkwater districts are formed from alluvial (stream or river sediments) and colluvial deposits (intermittent sedimentation) in gullies or small valleys and on the lower slopes of hillsides. The two districts have somewhat differing histories with respect of the landform genesis and ultimately on the soil patterns that were observed.

In the Kaituna/Havelock district, there is a clearly recognised stream sedimentation system, with the lower surfaces adjacent to the streams or rivers forming a distinct, although not widespread floodplain, above which is a clearly defined river terrace. At higher elevations there are terrace remnants belonging to an earlier period (or periods) of extensive sedimentation and valley infilling. These surfaces are often associated with fan sediments, or accumulations of debris that spilled out from local gullies. These earlier sedimentary accumulations probably relate to Last Glaciation climatic cycles during which periods of high intensity rain systems were experienced throughout the region as part of the glacial/interglacial climate change cycle (Campbell pers comm.).

In the Linkwater district, there is little evidence of a pronounced stream or river sedimentation system. Rather most of the land surfaces appear to have been constructed from sediment deposition from local gullies and small valleys, which accumulated fan type deposits of varied extent. However, the same pattern as seen in the Kaituna/Havelock district, of earlier extensive accumulation, followed by sediment removal then re-deposition is still evident (Campbell pers comm.).

3.2 Previous soil investigations

The valley floor soils of the Kaituna/Havelock and Linkwater districts were first identified during soil mapping of the region in the 1960's and published in 'Soils of South Island, New Zealand' Soil Bureau Bulletin 27 (New Zealand Soil Bureau, 1968). This mapping however was undertaken at a small scale i.e. 1:250 000 and as stated in the published bulletin 'the survey does not give more than a general picture of the soil pattern'. In the Soil Survey of South Island three soil units were recognised for the landforms in the Kaituna/Havelock and Linkwater districts i.e. Koromiko, Manaroa and Kaituna sets. The descriptions given in the Bulletin 27 for the soils and landscapes are not clearly diagnostic for each of the three soils and do not easily allow field identification to be made on the basis of landform.

The units shown on the map do not give a reliable indication of the soils as observed on the ground. The absence of clearly demarcated fluvial surfaces in the Linkwater district and also in some side valleys (e.g. Okaramio valley) makes identification of the soils somewhat difficult in the absence of more detailed soil maps which would be expected to resolve variations in the soil pattern. Furthermore a single soil profile description and basic soil chemistry from each profile is all there is available for each of these soils.

3.3 Soil Characteristics

In this investigation detailed soil profile descriptions were collected for the three soil families identified and previously mapped in the Kaituna/Havelock and Linkwater districts. This includes six Koromiko, eight Manaroa soil and five Kaituna soils (Appendix B). From each soil profile basic soil chemistry, trace elements and soil physical data was also collected from both topsoil and subsoils (Appendix A).

3.4 Koromiko Soil

The Koromiko family of soils appears to represent the soils on the lowest land surfaces (described in Bulletin 27 as occurring up to 50 ft above sea level). This topographic unit, as mapped, covers a range of conditions and includes soils on stream and river floodplains and low terraces as well as the toe slopes of some fans (Figure 2).



Figure 2. A lower terrace surface on which the Koromiko family of soils occur. The Atahaua stream is located to the right of the photo.

The Koromiko soils are derived from schistose alluvium. They are classified as a Recent soils in the New Zealand Soil Classification system (Hewitt, 2010). There was some variation in soil profile morphology which reflected that Koromiko soils were sampled on floodplains and low terraces as well as the toe slopes of some fans. Typically topsoil profiles were dark yellowish brown or dark brown, had a moderately developed fine polyhedral structure, weak soil strength and were friable. Subsoil characteristics were quite variable which reflected the fact that some profiles contained buried horizons. Profiles ranged between light olive brown to yellowish brown, had moderately developed coarse block structure and also weakly developed fine polyhedral structure, a weak to slightly firm soil strength and were very friable.

Some average soil physical and chemical properties for the six Koromiko family soils sampled are given in Table 1. Typically the Koromiko soils are generally moderately well to well drained, deep soils with a moderate to moderately rapid permeability. Topsoil textures are typically silt loams or heavy silt loams and textures very variable at depth ranging from sands to heavy clay loams.

Total available water was calculated for both the 0-30cm and 0-60cm soil depths. The 0-30 cm soil depth is particularly useful for soils where effluent is applied where the aim is to retain effluent within the root zone, while the deeper 0-60cm soil depth is useful for scheduling irrigation. For both soil depths storage capacity was classed as high.

Topsoil phosphate retention for the Koromiko soil was classed as medium. Phosphate retention is a measure of the ability of the soil to remove phosphorus from solution, holding onto it firmly, tending to make it 'slowly' available to plants. High P-retention values indicate that plants will give a lower response to the same amount of phosphate fertiliser than those plants on a soil with low P-retention.

Average topsoil cadmium concentrations were approximately double typical background concentrations found in soils (Roberts et al. 1994). The source of cadmium is most likely phosphate fertiliser which has been shown to contain cadmium as an incidental impurity. One Koromiko soil had a cadmium concentration approaching the suggested 0.6 mg/kg trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils (MAF, 2011).

Table 1. Average soil properties for the Koromiko family of soils

Overview	
Family:	Koromiko
Soil Classification:	Recent
Parent material origin:	Schistose alluvium
Average Physical properties	
Texture:	Silty
Potential rooting depth:	80 – 100cm
Soil depth:	Deep
Drainage class:	Moderately well to well
Permeability:	Moderate
Topsoil stones:	Stoneless
Top 30cm available water: (0-30cm)	103mm (range 86 – 113mm)
Top 60cm available water: (0-60cm)	170mm (range 123 – 209mm)
Topsoil bulk density:	1.2 g/cm ³
Subsoil bulk density:	1.4 g/cm ³
Chemical properties	
Topsoil organic matter:	5.0 - 9.3%
Topsoil P retention:	Medium (34%)
Topsoil cadmium:	0.36 mg/kg

3.5 Manaroa Soil

Manaroa soils occur on surfaces that are intermediate between the lower floodplains and the more elevated remnant terrace and fan surfaces. They are formed on both alluvial surfaces and fans (Figure 3).



Figure 3. The Manaroa soil located on a low lying fan deposit surface.

The Manaroa soils are derived from schistose alluvium and colluvium. They are classified as a Brown soil in the New Zealand Soil Classification system (Hewitt, 2010). Typically topsoil profiles were dark yellowish brown, had moderately developed fine polyhedral structure, weak soil strength and were friable. Subsoils were typically yellowish brown to light olive brown deeper in the profile, had a moderately developed fine polyhedral to medium/coarse blocky structure, a weak soil strength and were often firm, sometimes brittle at depth.

Some average soil physical and chemical properties for the eight Manaroa family soils sampled are given in Table 2. The Manaroa soils were generally well to moderately well drained soil (one imperfectly drained), moderately deep to deep soils with an estimated moderate permeability, although at a couple of sites with heavier textures permeability was estimated to be moderately slow. Topsoil textures are typically silt loams with subsoils either heavy silt loam and clay loams. Like for the Koromiko soil, total available water for both the 0-30cm and 0-60cm was classed as high.

Average topsoil phosphate retention for the Manaroa soil was classed as medium. Like for the Koromiko soil, average topsoil cadmium concentrations were approximately double background concentrations found in soils, although no soils had a cadmium concentration above the suggested 0.6 mg/kg trigger value outlined in the national strategy for managing risk caused by cadmium in agricultural soils.

Table 2. Average soil properties for the Manaroa family of soils

Overview	
Family:	Manaroa
Soil Classification:	Brown
Parent material origin:	Schistose alluvium and colluvium
Average Physical properties	
Texture:	Silty
Potential rooting depth:	70 – 90cm
Soil depth:	Moderately deep - deep
Drainage class:	Well to moderately well
Permeability:	Moderate – moderately rapid
Topsoil stones:	Very slightly stony
Top 30cm available water: (0-30cm)	85mm (range 71 – 92mm)
Top 60cm available water: (0-60cm)	133mm (range 105 – 163mm)
Topsoil bulk density:	1.1 g/cm ³
Subsoil bulk density:	1.3 g/cm ³
Chemical properties	
Topsoil organic matter:	7.6 - 10.9%
Topsoil P retention:	Medium (48%)
Topsoil cadmium:	0.35 mg/kg

3.6 Kaituna Soil

The Kaituna soils appear to represent the soils on terraces and fans that occur above the valley floors (Figure 4).

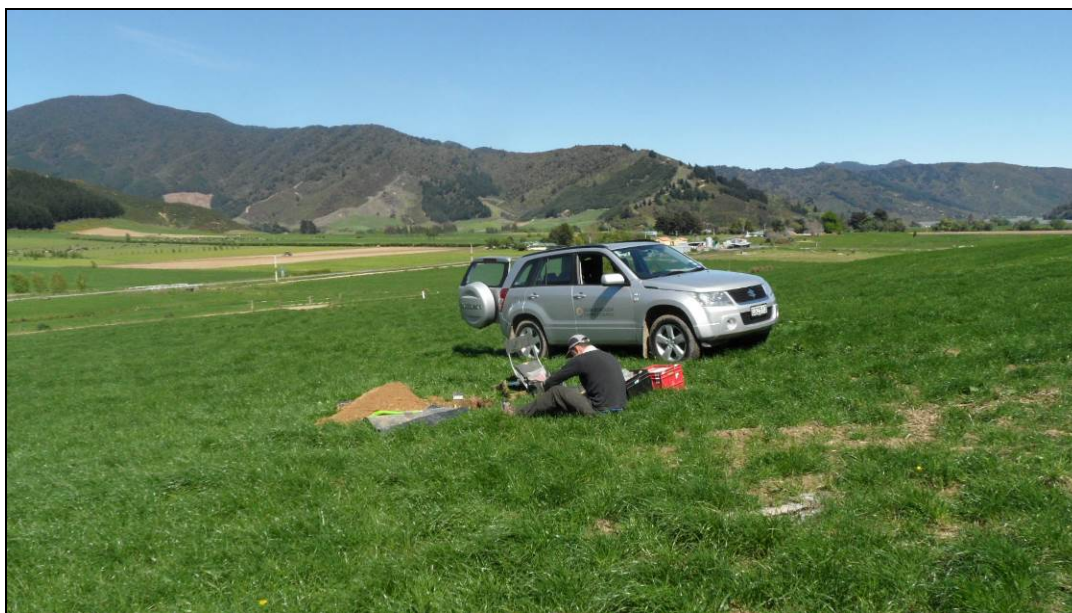


Figure 4. Kaituna soil occurring on a low fan above the valley floor in the Linkwater district.

The Kaituna soils are derived from schistose colluvium. They are classified as a Brown soil in the New Zealand Soil Classification system (Hewitt, 2010). Typically topsoil profiles were dark yellowish brown, had a strongly developed fine polyhedral structure, a weak soil strength and were friable. Subsoils were typically yellowish brown, had a moderately developed fine polyhedral structure, a weak to very weak soil strength and were very friable.

Some average soil physical and chemical properties for the five Kaituna family soils sampled are given in Table 3. The Kaituna soils were mainly well drained (one profile moderately drained), moderately deep to deep soils with a moderate to moderately rapid permeability. However, one profile had a moderately slow permeability which had a clay/clay loam subsoil. Topsoil textures ranged from silt loams to clay loams and very slightly sandy and stony at depth. Although again one profile on a mid slope fan had a clay subsoil. Total available water for both the 0-30cm and 0-60cm was classed as high.

Average topsoil phosphate retention for the Kaituna soil was classed as medium. Like for the Koromiko and Manaroa soils, average topsoil cadmium concentrations were approximately double background concentrations found in soils, although no soils had a cadmium concentration above the suggested 0.6 mg/kg trigger value outlined in the national strategy for managing risk caused by cadmium in agricultural soils.

Table 3. Average soil properties for the Kaituna family of soils

Overview	
Family:	Kaituna
Soil Classification:	Brown
Parent material origin:	Schistose colluvium
Average Physical properties	
Texture:	Silt – clay loam
Potential rooting depth:	75 - 90cm
Soil depth:	Moderately deep - deep
Drainage class:	Well
Permeability:	Moderate – moderately rapid
Topsoil stones:	Very slightly stony
Top 30cm available water: (0-30cm)	89mm (84 – 99mm)
Top 60cm available water: (0-60cm)	138mm (128 – 153mm)
Topsoil bulk density:	1.1 g/cm ³
Subsoil bulk density:	1.2 g/cm ³
Chemical properties	
Topsoil organic matter:	9.5 - 10.8%
Topsoil P retention:	Medium (58%)
Topsoil cadmium:	0.41 mg/kg

4. Summary

- Three soil families were identified in the Havelock-Kaituna and Linkwater districts i.e. Koromiko, Manaroa and Kaituna soils.
- The Koromiko family of soils occurs on the lower land surfaces – on stream and river floodplains and low terraces. The Manaroa family occurs on surfaces intermediate between the lower floodplains and remnant terrace and fan surface. The Kaituna family occurs on terraces and fans that occur above the valley floor.
- All three soils were generally well or moderately well drained, moderately deep to deep, moderate to moderately rapid permeability and have high water storage capacities – although there were some exceptions. These properties make the soils generally ‘low risk’ in terms of direct losses from land application of effluent because of their ability to store and treat effluent.
- Detailed, farm scale soil mapping (i.e. 1:5,000) would help separate soils within the families which aren’t as well drained or those with lower permeabilities and should be done on site specific basis when categorising the soil for effluent or irrigation application.

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Appendix A

Table A1 Soil chemical analysis from soil sampling pits

Site No.	Depth	pH	Olsen P	ASC	AMN	OM	Total C	Total N	C/N	K	Ca	Mg	Na	CEC	BS
			mg/L	%	µg/g	%	%	%		me/100g	me/100g	me/100g	me/100g	me/100g	%
Site 1	0 - 10 cm	5.7	34	59	168	10.9	6.3	0.56	11.2	0.41	8.6	0.63	0.08	23	43
	30 - 40cm	5.3	8	87	57	5	2.9	0.25	11.8	0.22	2.2	0.24	< 0.05	19	14
Site 2	0 - 10 cm	5.9	11	31	157	7.2	4.2	0.40	10.6	0.23	10.9	0.74	< 0.05	20	61
	25-35cm	6.0	8	32	31	2.4	1.4	0.07	21.4	0.04	1.9	0.18	< 0.05	7	29
Site 3	0 - 10 cm	5.5	33	62	179	9.9	5.7	0.56	10.3	0.37	6.9	0.45	< 0.05	22	34
	30 - 40cm	5.2	4	81	39	5.5	3.2	0.22	14.9	0.19	0.7	0.07	< 0.05	18	6
Site 4	0 - 10 cm	6.0	21	33	246	9.2	5.3	0.51	10.4	1.13	10.2	1.16	0.07	21	61
	30 - 40cm	5.5	2	40	54	1.8	1	0.12	8.5	0.23	2.5	0.26	0.05	12	26
Site 5	0 - 10 cm	5.9	30	34	175	6	3.5	0.42	8.3	0.19	11.5	1.31	0.06	23	58
	30 - 40cm	5.5	2	49	50	1.7	1	0.13	7.7	0.16	3.4	0.24	< 0.05	15	25
Site 6	0 - 10 cm	5.8	16	35	103	5	2.9	0.33	8.7	0.21	14.5	1.42	0.11	24	68
	30 - 40cm	5.9	3	51	18	2.1	1.2	0.17	7.3	0.19	13.9	1.82	0.14	24	66
Site 7	0 - 10 cm	6.2	22	27	120	6.5	3.8	0.36	10.6	0.25	7.6	1.97	0.1	15	65
	30 - 40cm	5.6	5	33	7	2.5	1.4	0.13	10.8	0.05	2.7	0.35	< 0.05	10	32
Site 8	0 - 10 cm	6.0	44	38	253	9.2	5.3	0.53	10.1	1.01	11.3	1.82	0.09	23	63
	30 - 40cm	5.6	9	50	51	4.2	2.4	0.18	13.8	0.99	4.1	0.38	0.1	17	33
Site 9	0 - 10 cm	6.1	16	38	242	7.9	4.6	0.47	9.8	0.33	12.8	1.57	0.1	23	64
	30 - 40cm	5.7	2	48	42	3	1.7	0.14	12.4	0.07	4.9	0.31	< 0.05	14	38
Site 10	0 - 10 cm	5.7	32	50	196	8.3	4.8	0.48	10.1	0.68	8.3	1.74	0.07	22	50
	30 - 40cm	5.6	6	69	45	4.1	2.4	0.18	13.1	0.1	2.5	0.36	< 0.05	15	20
Site 11	0 - 10 cm	5.8	38	49	273	9.7	5.6	0.53	10.6	0.16	7.7	1.11	0.05	20	45
	30 - 40cm	5.8	6	64	105	4.5	2.6	0.21	12.3	0.05	3	0.66	< 0.05	14	27
Site 12	0 - 10 cm	5.8	33	43	194	9.3	5.4	0.55	9.8	0.21	8.1	1.56	< 0.05	20	50
	30 - 40cm	5.6	4	54	106	3.7	2.2	0.23	9.3	0.12	3	0.57	0.12	14	27
Site 13	0 - 10 cm	5.6	75	50	299	10.5	6.1	0.59	10.3	1.52	6.2	1.2	< 0.05	23	40
	30 - 40cm	5.1	20	72	124	5.4	3.1	0.29	10.6	1	0.7	0.17	< 0.05	18	11
Site 14	0 - 10 cm	5.6	59	57	206	9.5	5.5	0.52	10.6	0.28	5.6	1.47	0.06	22	33
	30 - 40cm	5.4	11	75	132	6.9	4	0.31	12.8	0.11	2.1	0.67	< 0.05	18	16
Site 15	0 - 10 cm	6.0	35	50	206	7.6	4.4	0.48	9.2	1.29	7.3	1.2	0.08	19	53

Soil Properties in the Havelock/Kaituna and Linkwater Districts

Site No.	Depth	pH	Olsen P	ASC	AMN	OM	Total C	Total N	C/N	K	Ca	Mg	Na	CEC	BS
	30 - 40cm	5.4	12	64	64	2.9	1.7	0.19	8.7	0.22	1	0.15	< 0.05	14	10
Site 16	0 - 10 cm	6.2	13	36	118	5.2	3	0.3	10	0.12	11.5	0.48	< 0.05	18	69
	30 - 40cm	6.0	8	34	47	0.8	0.4	0.04	9.8	0.04	3.1	0.09	< 0.05	10	33
Site 17	0 - 10 cm	5.5	33	61	208	10.8	6.3	0.6	10.5	1.49	6.7	1.74	0.14	22	45
	30 - 40cm	5.2	5	81	101	5	2.9	0.25	11.6	0.15	0.9	0.2	< 0.05	14	9
Site 18	0 - 10 cm	5.3	19	63	138	10.5	6.1	0.54	11.2	1.09	6.1	1.11	0.09	22	38
	30 - 40cm	5.1	4	87	70	5.4	3.2	0.26	12.4	0.18	0.7	0.12	< 0.05	16	6
Site 19	0 - 10 cm	5.8	18	63	245	9.8	5.7	0.55	10.3	0.43	6.4	0.95	0.1	18	43
	30 - 40cm	5.7	4	78	79	4.5	2.6	0.24	11	0.08	1.7	0.14	0.07	13	15

Table A2 Soil physical analysis from soil sampling pits

Site No.	Depth	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air Filled Porosity	Vol. WC -5kPa	Vol. WC -10kPa	Vol. WC -100kPa	Vol. WC -1500kPa	Readily Available	Total Available
		(t/m ³)	(t/m ³)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 1	0 - 10 cm	0.9	2.5	63.3	6.6	8.8	56.7	54.5	45.9	25.4	8.6	29.2
	30 - 40cm	1.1	2.7	60.4	12.6	14.6	47.9	45.8	38.6	28.2	7.2	17.6
Site 2	0 - 10 cm	1.1	2.7	59.5	3.1	5.2	56.4	54.3	46.2	18.6	8.0	35.7
	25-35cm	1.3	2.8	53.0	8.0	9.4	45.1	43.6	33.5	11.5	10.2	32.2
Site 3	0 - 10 cm	0.9	2.6	64.4	4.7	7.3	59.7	57.1	48.2	24.2	9.0	33.0
	30 - 40cm	1.1	2.7	57.4	7.9	9.6	49.6	47.9	42.1	33.3	5.8	14.6
Site 4	0 - 10 cm	1.2	2.6	53.8	2.1	4.6	51.7	49.2	41.0	20.2	8.2	29.0
	30 - 40cm	1.6	2.8	40.6	2.4	3.5	38.2	37.2	32.0	25.1	5.2	12.1
Site 5	0 - 10 cm	1.1	2.7	57.4	<1	1.2	58.7	56.7	48.5	19.3	8.2	37.5
	30 - 40cm	1.5	2.8	44.7	3.2	4.1	41.5	40.6	34.6	25.4	6.1	15.1
Site 6	0 - 10 cm	1.2	2.7	54.1	<1	<1	56.1	54.9	47.6	24.3	7.3	30.6
	30 - 40cm	1.4	2.7	49.3	5.1	6.1	44.2	43.2	38.7	30.8	4.6	12.4
Site 7	0 - 10 cm	1.2	2.7	55.1	<1	2.2	55.2	53.0	45.2	15.4	7.7	37.6
	30 - 40cm	1.4	2.8	49.1	8.6	11.0	40.5	38.2	24.0	11.3	14.2	26.9
Site 8	0 - 10 cm	1.1	2.6	57.4	<1	2.5	56.5	54.9	46.4	25.5	8.5	29.5
	30 - 40cm	1.4	2.7	48.6	7.3	8.7	41.4	39.9	34.2	26.7	5.8	13.3
Site 9	0 - 10 cm	1.1	2.6	56.4	<1	1.3	57.6	56.1	49.6	25.8	6.5	30.4
	30 - 40cm	1.5	2.7	44.6	4.1	5.2	40.5	39.4	34.5	27.9	5.0	11.5
Site 10	0 - 10 cm	1.2	2.6	55.3	<1	1.3	56.1	54.0	47.6	25.2	6.4	28.8

Soil Properties in the Havelock/Kaituna and Linkwater Districts

Site No.	Depth	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air Filled Porosity	Vol. WC -5kPa	Vol. WC -10kPa	Vol. WC -100kPa	Vol. WC -1500kPa	Readily Available	Total Available
		(t/m ³)	(t/m ³)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
	30 - 40cm	1.3	2.7	53.9	11.9	14.5	42.0	39.4	31.7	21.5	7.7	18.0
Site 11	0 - 10 cm	1.1	2.6	55.5	<1	3.6	56.4	53.6	45.4	25.3	8.2	28.3
	30 - 40cm	1.3	2.7	50.6	5.7	7.8	45.0	42.8	34.9	24.6	7.9	18.2
Site 12	0 - 10 cm	1.1	2.6	59.4	2.4	5.4	57.1	54.1	45.4	25.4	8.7	28.7
	30 - 40cm	1.5	2.7	45.8	7.5	9.3	38.4	36.6	30.4	18.6	6.2	18.0
Site 13	0 - 10 cm	1.1	2.6	58.2	6.5	8.9	51.7	49.3	40.8	22.8	8.5	26.5
	30 - 40cm	1.1	2.7	57.7	11.5	13.8	46.2	43.9	35.9	25.8	8.1	18.1
Site 14	0 - 10 cm	1.1	2.6	56.3	3.0	5.7	55.3	53.0	47.0	24.1	6.1	28.9
	30 - 40cm	1.1	2.7	59.8	15.6	18.2	44.2	41.6	33.5	24.5	8.2	17.1
Site 15	0 - 10 cm	1.1	2.6	56.5	<1	1.7	56.8	54.9	48.0	24.2	6.9	30.6
	30 - 40cm	1.2	2.8	57.2	8.0	9.8	49.3	47.5	39.8	23.8	7.7	23.6
Site 16	0 - 10 cm	1.3	2.7	52.3	<1	<1	53.3	53.3	47.0	18.4	6.4	35.0
	30 - 40cm	1.3	2.8	51.9	6.5	8.5	45.4	43.4	32.8	12.7	10.6	30.8
Site 17	0 - 10 cm	1.1	2.6	57.6	5.3	8.0	52.2	49.6	42.7	21.6	6.9	28.0
	30 - 40cm	1.2	2.7	56.6	14.8	17.3	41.8	39.4	31.9	23.5	7.5	15.9
Site 18	0 - 10 cm	1.0	2.5	60.2	3.1	5.4	57.1	54.8	46.4	24.5	8.4	30.4
	30 - 40cm	1.1	2.7	58.0	15.0	17.4	43.0	40.7	33.9	25.3	6.8	15.3
Site 19	0 - 10 cm	1.1	2.6	56.5	3.0	5.6	53.5	50.9	43.3	27.2	7.6	23.7
	30 - 40cm	1.2	2.7	55.5	9.8	11.9	45.7	43.6	37.2	30.5	6.4	13.2

Table A3 Soil trace element concentrations (mg/kg) from soil sampling pits

Site No.	Depth	Zn mg/kg	Cu mg/kg	Cr mg/kg	As mg/kg	Pb mg/kg	Ni mg/kg	Hg mg/kg	Cd mg/kg
Site 1	0 - 10 cm	50	4	22	4.2	11	9	0.07	0.39
	30 - 40cm	48	< 4	25	4.0	12	10	0.11	0.08
Site 2	0 - 10 cm	59	11	16	4.2	11	11	0.03	0.34
	25-35cm	57	13	17	4.5	11	13	0.03	0.09
Site 3	0 - 10 cm	54	11	24	5.8	12	10	0.08	0.31
	30 - 40cm	52	11	27	6.0	13	11	0.12	0.08
Site 4	0 - 10 cm	46	8	19	3.3	8	11	0.03	0.25
	30 - 40cm	53	6	20	2.7	9	10	0.04	< 0.02
Site 5	0 - 10 cm	56	11	20	4.3	10	12	0.04	0.3
	30 - 40cm	52	9	19	2.8	11	10	0.05	0.02
Site 6	0 - 10 cm	75	12	35	7.1	22	27	0.04	0.39
	30 - 40cm	87	13	34	4.7	24	26	0.06	0.05
Site 7	0 - 10 cm	53	11	15	3.9	10	11	0.02	0.24
	30 - 40cm	50	10	15	3.3	9	11	0.02	0.1
Site 8	0 - 10 cm	64	9	35	4.2	11	17	0.04	0.38
	30 - 40cm	63	8	36	4.1	12	17	0.05	0.06
Site 9	0 - 10 cm	61	7	31	3.4	11	15	0.04	0.39
	30 - 40cm	60	8	37	3.1	11	18	0.05	0.04
Site 10	0 - 10 cm	77	10	34	4.4	28	17	0.06	0.42
	30 - 40cm	52	9	27	4.3	12	14	0.07	0.09
Site 11	0 - 10 cm	42	12	27	3.3	12	14	0.09	0.55
	30 - 40cm	34	8	21	2.7	13	9	0.12	0.04
Site 12	0 - 10 cm	55	10	25	3.5	10	13	0.07	0.58
	30 - 40cm	60	6	25	2.8	11	12	0.09	0.05
Site 13	0 - 10 cm	80	17	26	4.1	27	13	0.08	0.33
	30 - 40cm	52	15	23	3.2	13	10	0.12	0.06
Site 14	0 - 10 cm	59	12	25	4.0	11	12	0.09	0.55
	30 - 40cm	58	15	22	3.1	11	11	0.13	0.13
Site 15	0 - 10 cm	60	12	23	4.0	13	12	0.07	0.42
	30 - 40cm	58	12	20	3.4	10	11	0.09	0.07
Site 16	0 - 10 cm	51	13	17	5.2	9	11	0.04	0.31
	30 - 40cm	49	17	21	4.8	9	13	0.02	0.03
Site 17	0 - 10 cm	49	10	25	4.2	10	12	0.08	0.35
	30 - 40cm	50	11	28	3.7	11	13	0.11	0.05
Site 18	0 - 10 cm	35	5	23	3.8	10	8	0.09	0.27
	30 - 40cm	29	< 4	24	2.6	9	8	0.12	0.06
Site 19	0 - 10 cm	51	7	18	3.8	10	9	0.07	0.25
	30 - 40cm	55	7	32	3.5	11	13	0.1	0.06

Appendix B

Sample name: Site 1

Soil Name: Manaroa (34c)

GPS: 1661807 5420811

Land use: Dairy

Elevation: 38m

Slope: 0°

Soil material: Late last Glaciation Atahua Stream Schistose alluvium

Landscape: main valley floor terrace

Soil drainage: well

Horizon	Depth	Description
A	0-18cm	dark yellowish brown (10YR 4/6) silt loam; 1% medium stones; moderately developed medium polyhedral structure; compact packing; friable; many fine roots
AB	18-25cm	dark yellowish brown and yellowish brown 10YR 4/6+5/8) silt loam; 1% medium stones; moderately developed fine polyhedral
Bw	25-52cm	yellowish brown (10YR 5/8) heavy silt loam; 1% medium stones; moderately developed fine polyhedral and medium blocky structure; weak soil strength, compact packing; very friable; common fine roots
BC	52-64cm	light olive brown (2.5Y 6/4) sandy silt loam; 15% fine and medium stones; weakly developed fine polyhedral structure; weak soil strength; compact packing; very friable; common fine roots
C	64-72cm+	light olive brown to olive brown (2.5Y 5/6-4/4); sand; 45% fine to coarse stones; apedal; loose



Sample name: Site 2

Soil Name: Koromiko (34e)

GPS: 1661712 5420685

Land use: Dairy

Elevation: 38m

Slope: 0°

Soil material: Atahaua Stream recent schistose alluvium

Landscape: valley floor low terrace/floodplain

Soil drainage: well

Horizon	Depth	Description
A	0-16cm	dark yellowish brown (10YR 4/4) heavy silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
AB	16-21cm	dark yellowish brown and light olive brown (10YR 4/4 + 2.5Y /6) heavy silt loam weakly developed fine polyhedral structure weak soil strength; compact packing; friable; many fine roots
BC	21-75cm	light olive brown (2.5Y 6/4) heavy silt loam; weakly developed medium blocky structure; weak soil strength; compact packing; brittle; common fine roots
C	75-100cm	olive brown (2.5Y 4/4) sand; apedal; compact packing



Sample name: Site 3

Soil Name: Kaituna (34a)

GPS: 1661998 5421088

Land use: Dairy

Elevation: 57m

Slope: 7°

Soil material: Late Last Glaciation schistose fan colluvium

Landscape: valley side, truncated fan

Soil drainage: well



Horizon	Depth	Description
A	0-22cm	dark yellowish brown (10YR 4/6) silt loam; 2% fine and medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
AB	22-28cm	dark yellowish brown and yellowish brown (10YR 4/6+ 5/6) silt loam; 2% medium stones; moderately developed fine polyhedral structure; weak soil strength, compact packing; very friable; many fine roots
Bw1	28-56cm	yellowish brown (10YR 5/6) silt loam; 5% medium stones; strongly developed fine polyhedral structure; very weak soil strength; compact packing; many fine roots
Bw2	56cm-75cm	yellowish brown (10YR 5/6) silt loam; 7% fine and medium stones; strongly developed fine polyhedral and weak fine blocky structure; weak soil strength; compact packing; common fine roots
BC	75-90 cm+	yellowish brown (10YR 5/8) sandy silt loam; 10% fine and medium stones; weakly developed fine blocky and polyhedral structure; weak soil strength; compact packing; few fine roots
	on	Compact gravel

Sample name: Site 4

Soil Name: Manaroa (34c)

GPS: 1667187 5415450

Land use: Dairy

Elevation: 79m

Slope: 3°

Soil material: valley floor schistose colluvium

Landscape: narrow side valley with colluvial infilling

Soil drainage: moderately well



Horizon	Depth	Description
A	0-22cm	dark brown (10YR 3/3) heavy silt loam; 1% fine stones; moderately developed fine polyhedral structure; slightly firm soil strength; compact packing; friable; abundant fine roots
AB	22-29cm	dark brown and yellowish brown (10YR 3/3+5/8) clay loam; 1% fine stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
Bw1	29-52cm	yellowish brown to light olive brown (10YR 5/8-2.5YR 5/6) clay loam; 1% fine stones; moderately developed coarse blocky structure; weak soil strength; compact packing; brittle fracture; few fine roots
Bw2	52cm-68cm	yellowish brown to light olive brown (10YR 5/8-2.5YR 5/6) clay loam; 1% fine stones; 5% dark reddish brown (5YR 4/6) and 5% light yellowish brown (2.5Y 6/4) fine distinct mottles; slightly firm soil strength; compact packing; few fine roots
BC	68-85 cm+	Light olive brown to yellowish light yellowish brown (2.5Y 5/4-10YR 5/8) sandy clay loam; 1% fine stones; 5% light yellowish brown (2.5Y 6/4) fine mottles; weakly developed medium blocky structure; slightly firm soil strength; compact packing; brittle fracture; very few fine roots

Sample name: Site 5

Soil Name: Koromiko (34e)

GPS: 1667123 5415742

Land use: Dairy

Elevation: 75m

Slope: 0°

Soil material: Okaramio River schistose alluvium

Landscape: elongated valley, intermittent terrace surface

Soil drainage: moderately well



Horizon	Depth	Description
A	0-22cm	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
AB	22-28cm	dark brown and light olive brown (10YR 3/3 + 2.5Y 5/6) clay loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; few fine roots
B(g)	28-40cm	light olive brown (2.5Y 5/6) clay loam; 5% reddish brown (5YR 5/8) and 15% pale olive (5Y 6/3) fine distinct mottles; moderately developed coarse blocky structure; weak soil strength; compact packing; brittle failure; few fine roots
bB	40cm-80cm	yellowish brown (10YR 5/6) clay loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; few fine roots
b BC	80-100 cm+	light olive brown (2.5Y 5/6) silt loam; weakly developed fine polyhedral structure; weak soil strength; compact packing; friable

Sample name: Site 6

Soil Name: Koromiko (34e)

GPS: 1666183 5415691

Land use: Dairy

Elevation: 65m

Slope: 0°

Soil material: Okaramio side-valley schistose colluvium

Landscape: elongated valley, side-valley toe slope

Soil drainage: moderately well



Horizon	Depth	Description
A	0-18cm	dark greyish brown (10YR 4/2) heavy silt loam; 2% yellowish red fine distinct pug mottles; moderately developed fine polyhedral structure; weak soil strength, compact packing; friable; common fine roots
AB	18-23cm	dark greyish brown (10YR 4/2) and olive (5Y 5/4) clay loam; moderately developed medium blocky structure; slightly firm soil strength; compact packing; friable; common fine roots
BC1	23-35cm	olive (5Y 5/4) clay loam; 2% dark reddish brown (5YR 4/2) concretions; moderately developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
BCg	35cm-60cm	olive grey (5Y 4/2) clay loam; 25% yellowish brown (10YR 5/4) and 40% light olive brown (2.5Y 5/4) medium mottles; moderately developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
Cg	60-90 cm+	light olive brown (2.5Y 5/4) heavy clay loam; 35% yellowish brown (10YR 5/4) and 45% olive grey (5Y 5/2) coarse mottles; apedal; firm

Sample name: Site 7

Soil Name: Koromiko (34e)

GPS: 1664157 5424001

Land use: Dairy

Elevation: 20m

Slope: 0°

Soil material: Kaituna River schistose alluvium

Landscape: low valley terrace/floodplain

Soil drainage: moderately well



Horizon	Depth	Description
A	0-9cm	brown to dark brown (10YR 4/3) silt loam; 5% yellowish red (5YR 5/6) and 5% dark greyish brown (2.5Y 4/2) fine pug mottles; weakly developed fine polyhedral and medium blocky structure; very weak soil strength; compact packing; friable; common fine roots
AB	9-13cm	brown to dark brown (10YR 4/3) and light olive brown (2.5Y 5/6) fine sandy loam; weakly developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
BC	13-30cm	light olive brown (2.5Y 5/6) fine sandy loam; apedal; few charcoal particles; very weak soil strength; compact packing; few fine and few medium roots
b B	30cm-66cm	yellowish brown (10YR 5/4) fine sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; few fine roots
b BC	66-92 cm+	brownish yellow (10YR 6/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable

Sample name: Site 8

Soil Name: Manaroa (34c)

GPS: 1664319 5423875

Land use: Dairy

Elevation: 16m

Slope: 0°

Soil material: Kaituna River schistose alluvium

Landscape: low river terrace/floodplain

Soil drainage: well



Horizon	Depth	Description
A	0-16cm	dark yellowish brown (10YR 4/4) silt loam; 1% medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
AB	16-24cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) heavy silt loam; 1% medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw1	24-48cm	yellowish brown (10YR 5/6) clay loam; 3% medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; few fine roots
Bw2	48cm-68cm	yellowish brown (10YR 5/6) clay loam; 25% medium to coarse stones; moderately developed medium polyhedral structure; weak soil strength; compact packing; brittle; few fine roots
BC	68-78 cm+	yellowish brown (10YR 5/8) sandy silt loam; 45% medium to coarse stones; apedal
C	on	light olive brown fine to coarse, loose stony gravel

Sample name: Site 9

Soil Name: Manaroa (34c)

GPS: 1664384 5423776

Land use: Dairy

Elevation: 18m

Slope: 0°

Soil material: Kaituna River schistose alluvium

Landscape: main valley terrace, slightly lower-lying area

Soil drainage: imperfectly



Horizon	Depth	Description
A	0-20cm	brown to dark brown (10YR 4/3) silt loam; moderately developed fine polyhedral structure; slightly firm soil strength; compact packing; friable; many fine roots
Bw(g)1	20-30cm	light olive brown (2.5Y 5/6) clay loam; 7% red (2.5YR 4/8) and 5% pale olive (5Y 6/3) fine distinct mottles; moderately developed fine polyhedral and blocky structure; slightly firm soil strength; ; compact packing; friable; common fine roots
Bw(g)2	30-57cm	light olive brown (2.5Y 5/6) clay loam; 50% light olive brown (2.5Y 5/4) fine diffuse mottles; moderately developed fine polyhedral and medium blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
Bw(g)3	57cm-72cm	light yellowish brown (2.5Y 6/6) clay to clay loam; 5% fine stones; 25% red (2.5YR 5/6) and 50% olive (5Y 5/3) fine distinct mottles; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
BC	72-82 cm+	light olive brown (2.5Y 5/4) sandy silt loam; 30% fine to medium stones; 35% red (2.5YR 5/6) medium distinct mottles; apedal

Sample name: Site 10

Soil Name: Manaroa (34c)

GPS: 1664278 5423267

Land use: Dairy

Elevation: 16m

Slope: 0°

Soil material: Kaituna River schistose alluvium

Landscape: main valley terrace

Soil drainage: well



Horizon	Depth	Description
A	0-17cm	dark yellowish brown (10YR 4/4) silt loam; 2% fine and medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
AB	17-23cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/8) silt loam; 2% fine and medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw1	23-50cm	yellowish brown (10YR 5/8) silt loam; 5% fine to medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw2	50cm-64cm	yellowish brown (10YR 5/8) sandy silt loam; 15% fine to medium stones; moderately developed fine polyhedral and coarse blocky structure; weak soil strength; compact packing; friable; few fine roots
BC	64-72 cm+	light olive brown (2.5Y 5/6) loamy sand; 40% fine to medium stones; apedal; loose

Sample name: Site 11

Soil Name: Kaituna (34a)

GPS: 1672973 5428081

Land use: Dairy

Elevation: 24m

Slope: 6°

Soil material: schistose colluvium

Landscape: midslope fan

Soil drainage: moderately well



Horizon	Depth	Description
A	0-22cm	dark yellowish brown (10YR 3/6) heavy silt loam; 1% fine stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
AB	22-30cm	dark yellowish brown (10YR 3/6) and yellowish brown (10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw	30-52cm	yellowish brown (10YR 5/6) silt loam; 5% fine stones; moderately developed medium polyhedral structure; very weak soil strength; compact packing; friable; few fine roots
Bw(g)	52cm-70cm	brownish yellow (10YR 6/8) clay loam; 25% light brownish grey to light olive brown (2.5Y 6/2-6/4) and 20% strong brown (7.5YR 5/8) fine distinct mottles; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
BC(g)	70-93 cm+	light olive brown (2.5Y 5/4) clay to clay loam; 25% light olive brown (2.5Y 6/2) and 25% yellowish red (5YR 5/8) medium distinct mottles; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture

Sample name: Site 12

Soil Name: Koromiko (34e)

GPS: 1672954 5428302

Land use: Dairy

Elevation: 16m

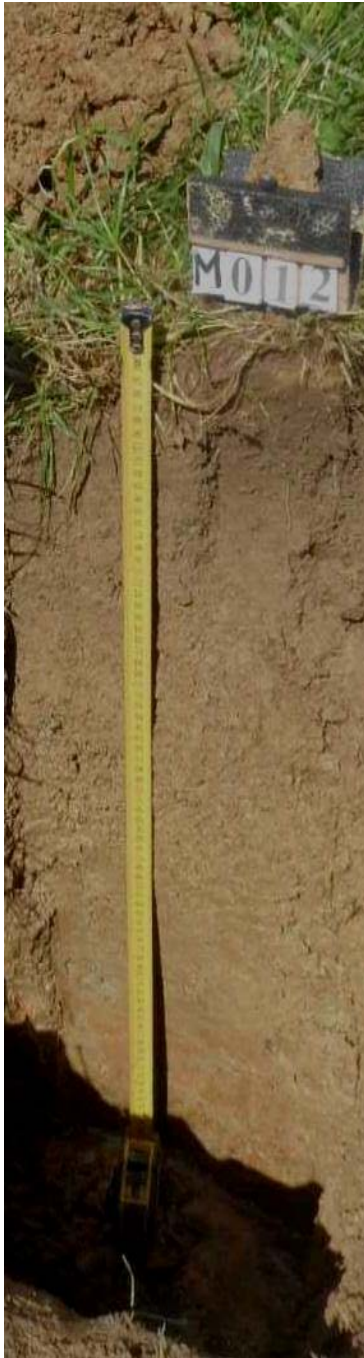
Slope: 0°

Soil material: schistose alluvium

Landscape: valley floor

Soil drainage: moderately well

Horizon Depth Description



A	0-16cm	dark yellowish brown (10YR 4/4) silt loam; 2% fine stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
AB	16-20cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) silt loam; 5% fine stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw	20-38cm	yellowish brown (10YR 5/6) silt loam; 7% fine and medium stones; 5% strong brown (7.5YR 5/6) and 5% light olive brown (2.5Y 6/4) fine and medium distinct mottles; moderately developed fine polyhedral structure; weak soil strength; compact packing; very friable; common fine roots
BC	38cm-58cm	yellowish brown to olive brown (10YR 5/6-2.5Y 5/6) heavy silt loam; 5% strong brown (7.5YR 5/8) and 5% light olive brown (2.5Y 5/4) fine and medium mottles; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture;
BCg	58-78 cm+	olive (5Y 5/3, 60%) and reddish brown (5YR 4/4, 40%) distinct medium mottled sandy clay loam; 2% fine stones; moderately developed medium polyhedral structure; slightly firm soil strength; compact packing; brittle fracture

Sample name: Site 13

Soil Name: Manaroa (34c)

GPS: 1672973 5428699

Land use: Dairy

Elevation: 9m

Slope: 4°

Soil material: schistose colluvium

Landscape: valley floor, midslope of fan

Soil drainage: well



Horizon	Depth	Description
A	0-21cm	dark yellowish brown (10YR 4/6) silt loam; 1% fine and medium stones; moderately developed fine and medium polyhedral structure; weak soil strength; compact packing; friable; common fine roots
AB	21-27cm	dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/8) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw1	27-42cm	yellowish brown (10YR 5/8) heavy silt loam; 1% fine and medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; few fine roots
Bw2	42cm-70cm	light olive brown (2.5Y 5/6) heavy silt loam to clay loam; 2% strong brown (7.5YR 5/8) and 2% light yellowish brown (2.5Y 6/4) fine mottles; weakly developed coarse blocky structure; very weak soil strength; compact packing; very friable; few fine roots
BC	70-85 cm+	light olive brown (2.5Y 5/6) sand; 50% fine to coarse stones; apedal; compact

Sample name: Site 14

Soil Name: Kaituna (34a)

GPS: 1673163 5428927

Land use: Dairy

Elevation: 23m

Slope: 6°

Soil material: schistose colluvium

Landscape: valley side, upper slope of fan

Soil drainage: well

Horizon	Depth	Description
A	0-18cm	dark yellowish brown (10YR 4/6) clay loam; 3% fine and medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
AB	18-23cm	dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/6) clay loam; 3% fine to medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; very friable; common fine roots
Bw1	23-42cm	yellowish brown (10YR 5/6) silt loam; 3% fine to medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; very friable; common fine roots
Bw2	42cm-80cm	yellowish brown (10YR 5/6) sandy silt loam; 30% fine to coarse stones; weakly developed fine polyhedral structure; weak soil strength; compact packing; very friable; few fine roots



Sample name: Site 15

Soil Name: Manaroa (34c)

GPS: 1671913 5428589

Land use: Dairy

Elevation: 7m

Slope: 3°

Soil material: schistose colluvium

Landscape: gently sloping valley floor infilling

Soil drainage: moderately well



Horizon	Depth	Description
A	0-20cm	dark yellowish brown (10YR 4/4) silt to silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
AB	20-28cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) silt to silt loam; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
Bw	28-45cm	yellowish brown (10YR 5/6) silt to silt loam; moderately developed fine polyhedral structure and coarse blocky structure; weak soil strength; compact packing; friable; few fine roots
BC	45cm-67cm	light olive brown (2.5Y 5/6) silt loam to heavy silt loam; 5% pale olive (2.5Y 6/4) fine mottles; weakly developed coarse blocky structure; very weak soils strength; compact packing; very friable; few fine roots
C	67-92cm	dark yellowish brown (10YR 4/6 30%) and pale olive (2.5Y 6/4 60%) mottled heavy silt loam to silt loam; apedal; weak soil strength; compact packing; friable; few fine roots

Sample name: Site 16

Soil Name: Koromiko (34e)

GPS: 1671964 5427859

Land use: Dairy

Elevation: 15m

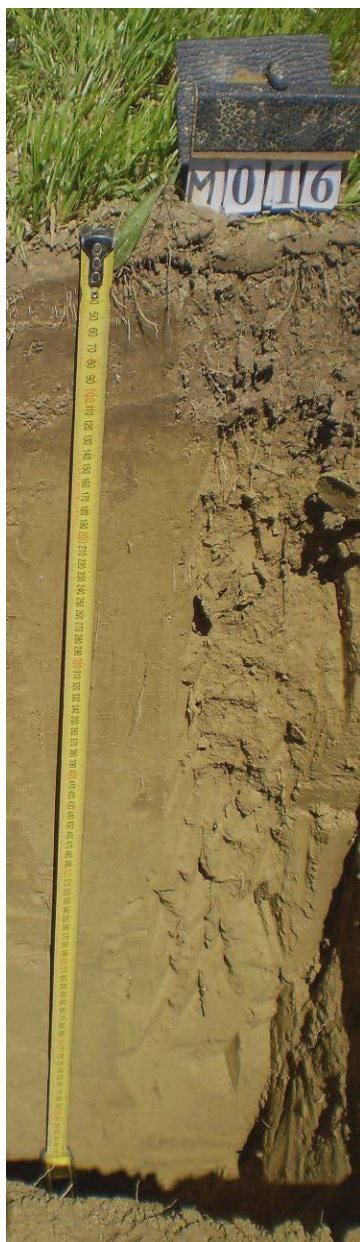
Slope: 3°

Soil material: schistose alluvium

Landscape: weak stream terracing in recent valley floor sediments

Soil drainage: well

Horizon	Depth	Description
A	0-16cm	brown to dark brown (10YR 4/3) silt to silt loam; weakly developed fine polyhedral structure; weak soil strength; compact packing; friable; many fine roots
AB	16-22cm	yellowish brown (10YR 5/6) and brown to dark brown (10YR 4/3) silt to silt loam; weakly developed fine polyhedral and coarse blocky structure; weak soil strength; compact packing; friable; many fine roots
Bw	22-40cm	yellowish brown (10YR 5/6) silt to silt loam; weakly develop coarse blocky structure; weak soil strength; compact packing; friable; common fine roots
BC	40cm-60cm	light olive brown (2.5Y 5/6) silt to silt loam; 20% light brownish grey (2.5Y 6/2) to light yellowish brown (2.5Y 6/4) fine distinct mottles; apedal; weak soil strength; compact packing; friable; few fine roots
C	60-100cm	light olive brown (2.5Y 5/6) heavy silt loam; apedal; weak soil strength; compact packing; friable



Sample name: Site 17

Soil Name: Kaituna (34a)

GPS: 1672169 5428360

Land use: Dairy

Elevation: 25m

Slope: 3°

Soil material: schistose alluvium

Landscape: terrace remnant of once more extensive side valley, Last Glaciation, fan-type infill deposits

Soil drainage: well



Horizon	Depth	Description
A	0-21cm	dark yellowish brown (10YR 4/4) silt loam; 2% fine stones; strongly developed fine polyhedral structure; weak soil strength; compact to loose packing; very friable; abundant fine roots
AB	21-27cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) silt loam; 2% fine stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; very friable; abundant fine roots
Bw1	27-50cm	yellowish brown (10YR 5/6) heavy silt loam; 5% fine stones; moderately developed fine polyhedral structure; very weak soil strength; compact packing; very friable; many fine roots
Bw2	50cm-67cm	yellowish brown (10YR 5/6) to light olive brown (2.5Y 5/6) heavy silt loam; 5% fine stones; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; common fine roots
BC	67-90cm+	light olive brown (2.5Y 5/4) to light yellowish brown (2.5Y 6/4) silt loam; 5% fine stones; 5% yellowish red (5YR 5/6) faint fine mottles; apedal; slightly firm soil strength; compact packing

Sample name: Site 18

Soil Name: Kaituna (34a)

GPS: 1671847 5430264

Land use: Dairy

Elevation:35m

Slope: 0°

Soil material: schistose colluvium

Landscape: weakly dissected older fan surface

Soil drainage: well



Horizon	Depth	Description
A	0-17cm	dark yellowish brown (10YR 4/6) clay loam; 5% fine and medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
AB	17-24cm	dark yellowish brown (10YR 4/6) and yellowish brown (10YR 5/8) clay loam; 5% fine and medium stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
Bw1	24-42cm	yellowish brown (10YR 5/8) clay loam; 10% fine to coarse stones; strongly developed fine polyhedral structure; weak soil strength; compact packing; very friable; many fine roots
Bw2	42cm-60cm	yellowish brown to brownish yellow (10YR 5/8-6/8) sandy silt loam; 20% fine to coarse stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; common fine roots
BC	60-75cm+	light olive brown (2.5Y 5/6) to olive yellow (2.5Y 6/6) sandy silt loam; 25% fine to coarse stones; weakly developed coarse blocky structure; slightly firm; compact packing; brittle fracture

Sample name: Site 19

Soil Name: Manaroa (34c)

GPS: 1671818 5429775

Land use: Dairy

Elevation: 3m

Slope: 2°

Soil material: schistose colluvium

Landscape: weakly dissected low-lying fan surface

Soil drainage: moderately well



Horizon	Depth	Description
A	0-23cm	dark yellowish brown (10YR 4/4) silt loam; 1% fine stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
AB	23-30cm	dark yellowish brown (10YR 4/4) and yellowish brown (10YR 5/6) silt loam; 1% fine and medium stones; moderately developed fine polyhedral structure; weak soil strength; compact packing; friable; abundant fine roots
Bw1	30-48cm	yellowish brown (10YR 5/6) heavy silt loam; 2% fine and medium stones; moderately developed fine polyhedral and coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
BC	48cm-70cm	light olive brown (2.5Y 5/6) clay loam; 15% fine and medium stones; weakly developed coarse blocky structure; slightly firm soil strength; compact packing; brittle fracture; few fine roots
C	70-80cm+	light olive brown (2.5Y 5/6) clay loam; 25% fine and medium stones; 25% strong brown (7.5YR 5/6) and 25% light yellowish brown (2.5Y 6/4) medium distinct mottles; apedal; dense