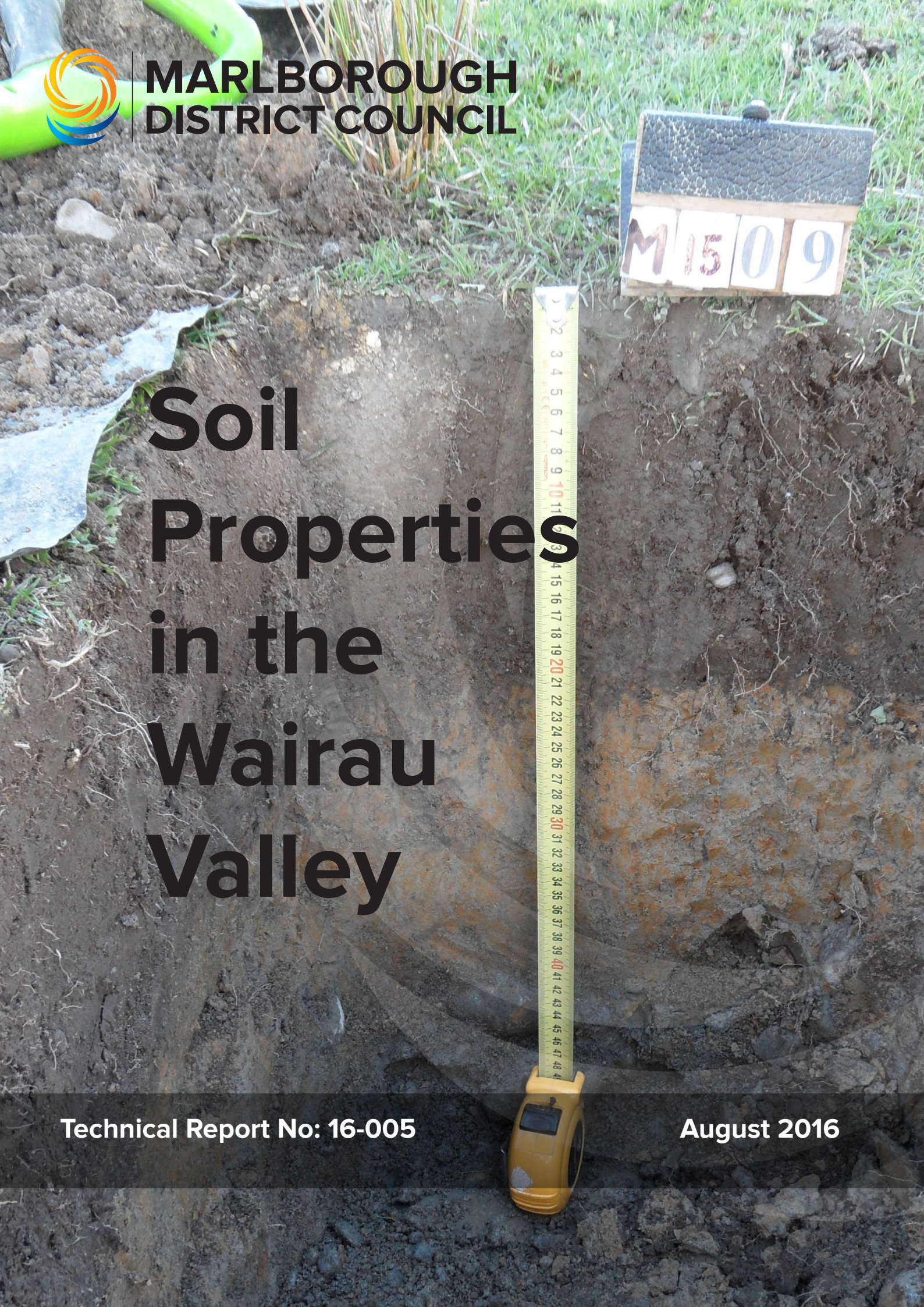

MARLBOROUGH DISTRICT COUNCIL

Soil Properties in the Wairau Valley

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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 little, or more often, no soils information available. An example is the Wairau Valley where there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This information is useful if we want to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management. 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 Wairau Valley 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.

The soil sampling work has been completed at a scale that provides guidance about the range of soil properties that might be encountered within the Middle Wairau Valley, but further detailed site-specific work would be required on a farm scale for use in determining best practice for effluent discharge and irrigation.

A series of soil auger observations were made across a range of sites in the Wairau Valley to identify the dominant soil types. Thirty-six soil profiles were described with topsoils and subsoils sampled and analysed for a range of soil physical and chemical properties.

Ten soil families were identified in the Wairau Valley. The Awatere, Wairau, Wairau mottled and Omaka, families of soils occur on the lower terrace systems of the valley floor. The intermediate terraces are occupied by Hillersden and Broadbridge soils. Renwick soils occupy fan surfaces that have outwashed from adjacent hills that surround the valley floor. Spring Creek soils can be found in low or intermediate terrace areas that are poorly drained. Marama soils occupy sites that are formed by small local streams and their nearby terraces. Jordon soils occupy a single loess covered high terrace location.

The Awatere, Wairau, Wairau mottled, Omaka, Hillersden, Renwick, Marama, Jordon soils (29 sites) were generally well or moderately drained and have moderately rapid permeability and high water storage capacities. These properties lower risk of direct losses from land application of effluent because of their ability to store and treat effluent

The Broadbridge and Spring creek soils (7 sites) were poorly or imperfectly drained, have slow to moderately slow permeability and have high water storage capacities. These properties make the soils generally higher risk in terms of direct losses from land application of effluent.

Contents

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 little, or more often, no soils information available. An example is the Wairau Valley where there is no available information on important soil parameters such as water holding capacity, drainage, soil depth and permeability. This information is critical in order to help landowners manage their soils for activities such as irrigation scheduling, effluent application, stock management.

In addition, detailed soil physical information is 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 Effluent Storage 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 and use water as well as protect our important soil resources.

The purpose of the soil investigation in Wairau Valley is to obtain data on a range of soil properties to assist both farmers and Council in the processes of land management. Data from the soil samples that have been collected will provide information on a range of soil chemical properties and also some soil physical properties including bulk density, porosity and water capacity, which are important in respect of stock management and the disposal of effluent by irrigation. The soil sampling work in this project is at a large scale to provide guidance but further detailed site specific work would be required on a farm scale for use in determining best practice for effluent discharge and irrigation.

1.1. Aim

The aim of this project is to describe and sample soils from representative sites in the Wairau Valley 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

Soil samplings were carried out from 36 sites along the Wairau Valley (Figure 1). An initial examination of the middle Wairau Valley floor topography from aerial photographs, suggested that the earlier identified soil pattern that is associated with the fluvial terrace system, was much more complex due to the contributions of sediments from small valleys and gullies onto the valley floor surfaces. In addition, some reworking of the valley floor sediments was apparent through the action of small intermittent streams, which in places wander across the valley floor.

Because of constraints that limited the ability to carry out detailed soil mapping of middle Wairau Valley, it was concluded that an assessment would best be made by examining the soils on a number of transects across the valley floor over the length of middle Wairau Valley. The transect locations (Fig 1.) were chosen in order to sample the range of landscape features observed in the aerial photos, although some potential transect locations were not used due to unavailability of access. The 36 sample areas (Fig 1.) were selected on the basis of aerial photo examinations, with individual site locations chosen to represent

expected differences across the landscape. At each site, holes were drilled with a soil auger to see how closely the soil fitted with the perceived soil-landscape model and to check for local soil variability. Surfaces that were extremely stony and bouldery were avoided for soil sampling owing to difficulties in extracting core samples for physical analyses. At the chosen sampling point, a pit was excavated (generally between 65-90cm depth) to establish where possible, the depth of the soil weathering zone. The depth of weathering zone and the soil properties developed within it are the key criteria in distinguishing the different soil groupings and confirming the relationship between the various soils identified and the landform units (terraces, fans etc.). Before sampling, each soil was described using the established New Zealand standard description criteria outlined by Milne, Clayton, Singleton and Wilson (1995). The soil sampling from 36 transect sites was undertaken during May 2015.

2.2. Soil Sampling

At each site, a 30m transect was laid out in a direction of least ground surface variability and topsoil horizon (0-7.5cm depth) cores were obtained at 2m intervals and bulked for soil chemical analyses. At the 15m positions, a soil pit was excavated typically into unweathered or little weathered subsurface material, or where very stony gravel restricted the acquisition of additional useful information. At each pit site, an undisturbed topsoil core sample was obtained (0-7.5cm ring depths) for physical analyses and another 7.5cm ring sample generally commencing at the surface of the B horizon. A bulk topsoil sample (0-20cm depth) was obtained for soil chemical analyses as well as a 10cm thick subsoil sample usually beginning at the surface of the B horizon.

2.3. Soil Analyses

2.3.1. Chemical

All soil chemical analyses were undertaken by Hill Laboratories, Hamilton. Soil pH was measured in water using glass electrodes and a 2:1 water to soil ratio (Blackmore, Searle and Daly, 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 and measuring the phosphate concentration by the molybdenum blue method (Olsen, Cole, Watanabe and Dean, 1954). Exchangeable cations i.e. Ca, Mg, K and Na were determined by extraction in ammonium acetate at pH 7 and analysed by ICP-OES (Hills (a), 2016). Anion storage capacity (Phosphate retention) was determined by equilibrium with 0.02 M potassium phosphate and analysis by ICP-OES (Hills (b), 2016). Anaerobically mineralisable nitrogen (AMN) was estimated by the anaerobic incubation method. The increase in NH_4-N concentration was measured after incubation for 7 days at 40 ºC and extraction in 2 M KCl (Keeney and Bremner, 1966). 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 (Martin, Creed and Brockhoff, 1994).

Commonly used soil chemical properties are summarised and given a general ranking in the following text. The ranking systems are the same as those used by Hills Laboratories.

Anion storage Capacity (%)			**Cation Exchange Capacity** **(milli-equivalents per 100 grams)**	
Very high	>80%		Very High	40
High	60 – 80%		High	25 -40
Medium	30 – 59%		Medium	12-25
Low	10 – 29%		Low	5-12
Very Low	<10%			

2.3.2. Physical

Soil physical analyses were 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 (Day, 1965). Soil water moisture content was determined at -5, -10, -20, -40, -100 and -1500 kPa tensions. This data was used to calculate Plant Available Water (PAW) at the 0-30mm and 0-60mm soil

depth. Plant Available Water is the amount of water (in mm) that can be extracted by plants between field capacity (-10kPa suction) and permanent wilting point (-1500 kPa). Plant 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 (Mclaren and Cameron, 1996). The methodology used to calculate Plant Available Water values as noted in the following text can be found in Appendix A (pg 42). Note that PAW values reported in the text are family averages derived from all samples for that family.

Location of the sampling site are shown in Fig1a-1c. Key for Figure 1a-1c

Soil Family	
Awatere	Aw
Wairau	Wr
Wairau mottled	Wrm
Spring Creek	Sc
Omaka	Om
Hillersden	Hil
Renwick	Rn
Broadbridge	Br
Marama	Ma
Jordon	Jd

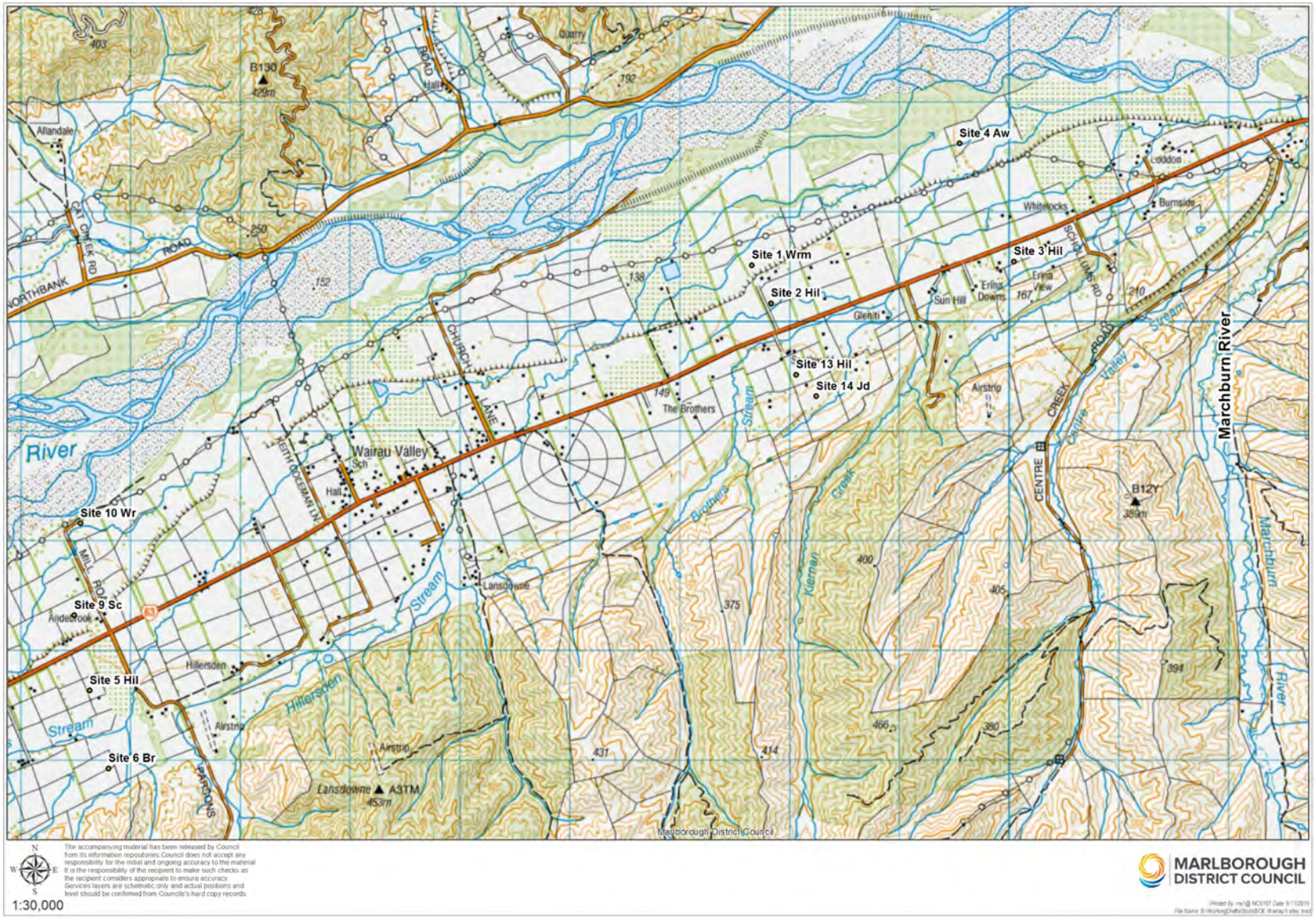

Figure 1a. Location of soil sampling sites

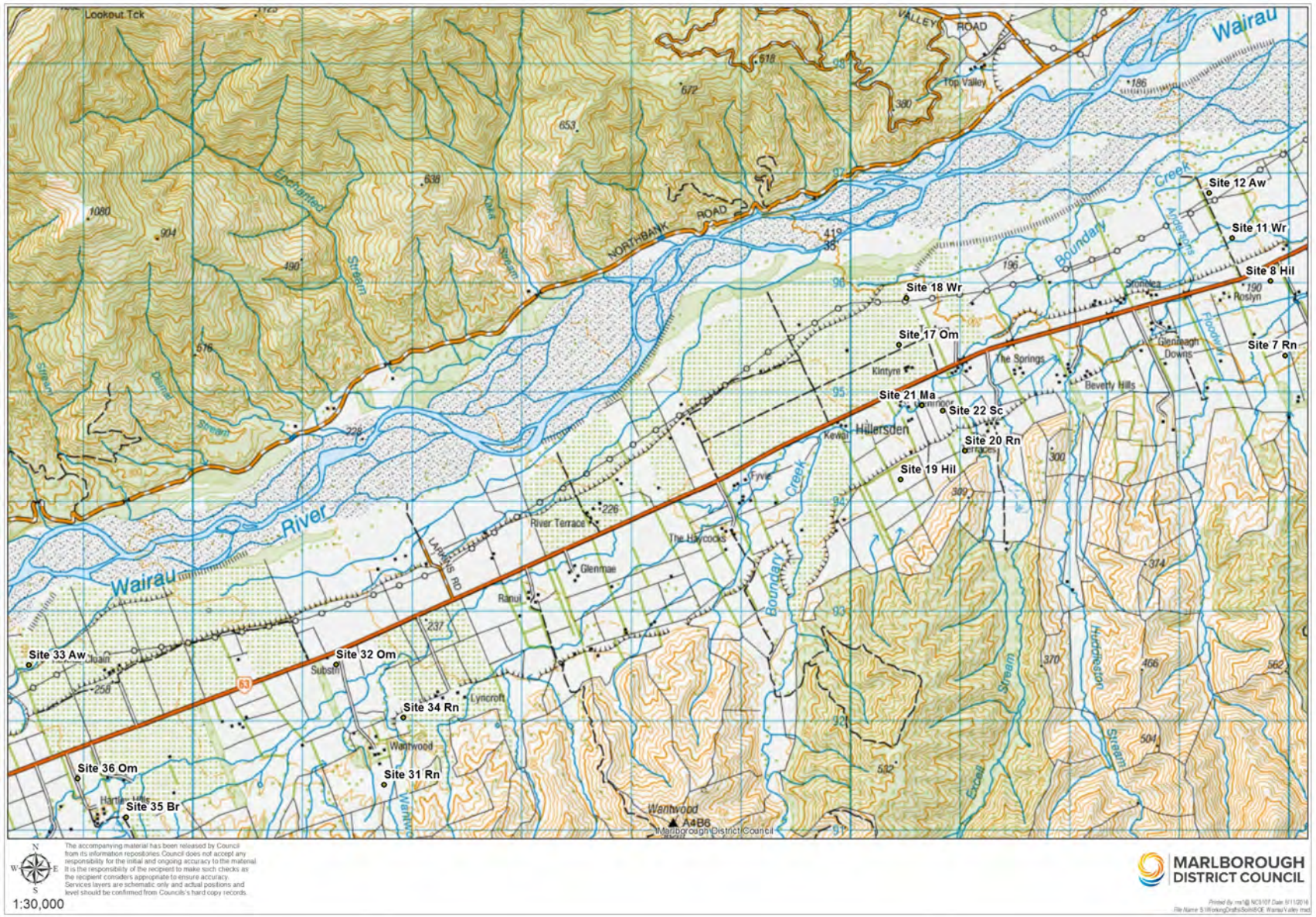

Figure 1b. Location of soil sampling sites

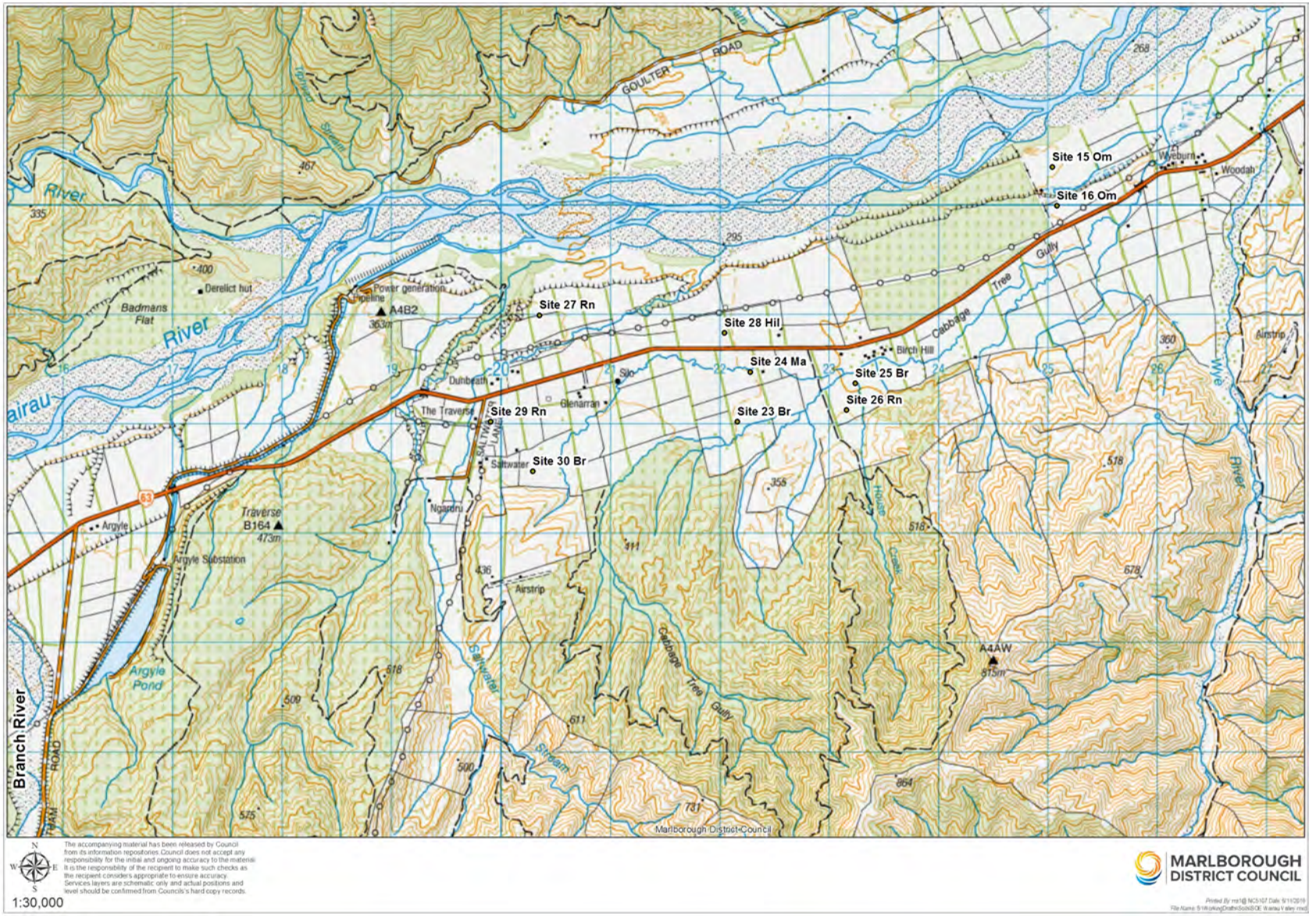

Figure 1c. Location of soil sampling sites

3. Results and Discussion

3.1. General Setting

The middle Wairau Valley, between Marchburn Creek and the Branch River, is a distinctive geomorphic entity with a narrow valley floor, approximately 3km wide, trending in a northeast-southwest direction over about 35 km between two mountain ranges (Fig. 1). The valley floor comprises a series of prominent terraces of Late Quaternary to Holocene age, predominantly on the south side of the Wairau River, which occupies a broad braided channel. Wairau Valley owes its existence to the *Wairau Fault*, a part of the onshore boundary of the Australian and Pacific crustal plates. Along the north side of the valley, Palaeozoic rocks that form the Richmond Range (sedimentary, schist and ultramafic rocks etc.) have been progressively rafted northwards along the Alpine Fault over a period of 25+ million yr (Kamp 1992). On the south side, ongoing faulting, and uplifting of the Mesozoic greywacke crustal blocks and subsequent extensive landscape dissection have resulted in the formation of many northward-aligned streams and gullies that discharge into the south side of the Wairau Valley.

The eastern end of this segment of Wairau Valley lies at an altitude of around 100m above sea level and the western end at Saltwater Creek, approximately 350m above sea level. Rainfall at Wairau Valley (between 2000 and 2012; World Weather online, https://www.worldweatheronline.com/) averaged approximately 1000mm, relatively evenly distributed but with maximum in June, July and August and minimum in February and March. Throughout the valley floor, there is little variation in the annual rainfall, apart from a small increase from around 900mm in the east to >1000mm in the west. There is however, a strong rainfall gradient northwards into the adjacent Richmond Range due to a rain shadow effect but a much less pronounced rainfall gradient into adjacent mountains to the southeast. Throughout the year, maximum temperature averaged about 17ºC while minimum temperatures averaged approximately 10ºC. (World Weather on line, https://www.worldweatheronline.com/).

Landuse in middle Wairau Valley was, until late last century, largely traditional sheep and cattle grazing. However, since the extensive development in the late 1970's of viticulture in the lower Wairau, grape planting has more recently spread, and continues to spread into middle Wairau Valley. Likewise, the intensification of dairy farming in New Zealand over the past few decades has seen some extension of this form of land use into middle Wairau Valley. With these intensified forms of landuse has come the need for a greater level of knowledge about the soil resources of the area, to enable the Marlborough District Council to effectively oversee the management of the soil and water resources of the region.

3.2. The Geomorphic Setting

As predicted from the initial examination of aerial photos, the soil pattern in middle Wairau Valley is closely related to the Late Quaternary geologic and geomorphic history of the region. The low terraces are characterised by soils formed on gravelly deposits of the Late Post-glacial to Holocene Rapaura Formation, dated between 3000-8000yrs BP (Brown 1981) with the surface sediments likely to be much younger. These deposits probably originate as a result of the Post Glacial retreat and warming which took place in the upper reaches of the Wairau River system (McCalpin 1992). The low terraces have numerous minor steps, possibly related to other climatic perturbations and can be grouped into three distinct levels. The bottom surface comprises an older floodplain level, probably formed during extreme flood events. The next two surfaces are clearly above flood level with the highest in some places being the most extensive surface in the valley and showing distinct soil weathering horizons. The soils on each of these surfaces vary considerably in depth and texture ranging from shallow and extremely stony (bouldery) to deep silty to sandy. In places on these surfaces, there are small streams flowing in low lying previous back channel areas, with water possibly derived from springs and present day runoff flows. In these places, mottled soils with impeded drainage are present.

The intermediate terrace towards the east lies about 4-5m above the lower terraces of middle Wairau Valley and is formed from Speargrass Formation Late Last Glaciation outwash gravels (14 000 to >20 000 years BP, Basher, Lynn, Whitehouse, 1995, Suggate 1965, Brown 1981). This surface has a somewhat more complex soil pattern than that of the low terrace system. Like the low terrace system however, there are small steps on this surface that represent downcutting episodes after the maximum glacial outwash, but fluvial channelling is less pronounced. A number of incipient streams or water-courses, which are mostly dry except in periods of intense storms, flow on this intermediate terrace

surface. Their source is the numerous valleys in the hills to the south (the largest of these being the Wye) with water sometimes appearing near fan toe slopes. Toward the western end of middle Wairau Valley, the intermediate terrace is about 9-10m above the lower terraces, in places persisting only as smaller remnants alongside the southern hills, with the increased height above river level representing an apparent diverging of terrace surfaces up-valley.

High terraces in middle Wairau Valley, about 50m above river level, are represented by only a few remnants of undulating dissected old terrace land along the footslopes of the southern hills. They are underlain by compact gravels of early or pre-Otirian glacial time and the surface has a veneer of loess, which was emplaced during later cold-climate glacial episodes.

The southern margin of middle Wairau Valley is distinguished by the numerous gullies and associated streams of various sizes that spill out onto the valley floor terraces forming small to medium sized fans. The fan deposits, for the most part comprise medium gravel, which become coarser towards valley heads, while finer textured sediments with impeded drainage are present around the toe slopes. Layers of finer sediment are often present within the gravel. The fan surfaces generally have a uniform (± 3º) grade towards the valley heads and appear to post-date the Speargrass Formation deposits. The general uniformity and extent of these fan deposits throughout the area suggests that they were deposited during a period of intense rainfall, perhaps a climatic variation that followed the end of the last glacial period.

The floodplain surface is a braided channel surface, with intermittent scrubby or willow vegetation and with surface sediments varying from deeper sands and silts to boulders. This surface is unused for agriculture owing to the high frequency of floods with 1-30 year return periods and was not examined.

3.3. Previous Soil Investigations

The first published soil map for middle Wairau Valley was by Harris and Birrell (1939). This survey covered the area from the south side of the river at Blenheim (survey boundary South Island Main Trunk Railway) to the Wye River. It illustrated the relationship that exists there between the recent soils on the lower terraces and lower flood plain surfaces with the extensive Post Glacial to Recent aggradation of Rapaura Formation sediments as described by Brown (1981). It also distinguished the older soils on higher surfaces that are associated with the Late Pleistocene glacial outwash gravels of the Speargrass Formation (Suggate 1965, Brown 1981). The soils identified for middle Wairau Valley were Upper Wairau soils on middle and low terraces (distinguished from Wairau series on deeper and younger sediments near Renwick) and Briary and Hillersden soils on the older terraces and fan surfaces. Soils with drainage imperfections were identified as a ‘meadow phase’.

In a generalised survey of the soils of Awatere, Kaikoura and part Marlborough Counties (1: 250 000 scale; Gibbs & Beggs 1953), the soils on the middle Wairau Valley floodplain and lower terraces were separated as Wairau and Omaka soils, the former on the lowest terraces and the latter on slightly higher surfaces and the equivalent of the Upper Wairau soils of Harris and Birrell (1939). Hillersden soils were once again mapped on the higher terrace surfaces, however at the eastern end of middle Wairau Valley, the higher terrace soils were separated as Renwick soils on the basis of soil colour (weathering) differences.

In the General Survey of Soils Of South Island (Soil Bureau Staff 1968, 1:250 000 scale), the soils of the lower terrace surfaces in middle Wairau Valley were included within the Waimakariri Set, which encompasses, with little distinction, all the widely occurring South Island soils of Recent age formed from greywacke alluvium. The soils on the higher terrace surfaces were mapped within the Hororata Set, which also occurs throughout the South Island.

In the Lower Awatere Valley, soils there were mapped in the late 1970’s (Campbell 2007; soil map prepared by Landcare Research 2007 from unpublished soil survey data) and in this survey, soils on the low terraces with increasing elevation, were respectively mapped as Awatere, Wairau and Omaka, with Dashwood soils (from gravels) and Seddon soils (from loess) on the main Late Pleistocene aggradational valley surface. Soils that were formed on Late Pleistocene-Holocene aged colluvial fan sediments were distinguished as Warwick soils.

The soils of the lower Wairau Plains between Blenheim and Renwick and including the floors of the smaller valleys to the immediate south were re-mapped at 1:25 000 scale by Laffan and Vincent (1990)

as part of a Marlborough Catchment and Regional Water Board assessment of the water and soil resources of the lower Wairau Plains. This survey distinguished 8 new soil series based on soil profile form (soil depth and horizon development and soil drainage criteria). Renwick soils, along with several other associated soils that were separated on soil depth, horizon and drainage differences, were mapped on the older stream/fan surfaces of the southern valleys.

3.4. Soil Characteristics

In this investigation detailed soil profile descriptions were collected at each site (Appendix B). From each soil profile basic soil chemistry, trace elements and soil physical data was also collected from samples of the topsoils and subsoils (Appendix A).

Soil Chemistry

The results of the soil chemical analyses are given in Table A1 (Appendix 1).

One feature of note in the analyses results is that within the groupings of the various soils, there is commonly an appreciable variation in the values for many of the individual chemical properties for which analyses were carried out. There are however some distinct differences and trends between the various soil groups.

The youngest soils (Awatere) show as expected, least evidence of chemical weathering with topsoil and subsoil base saturation values that are similar. Anion storage capacity values (P retention) are low. Wairau and Omaka soils on higher levels of the low terraces show somewhat more evidence of soil weathering processes with subsoil base saturation and cation exchange values that are generally much lower (50-60%) than those in the surface soil horizons. The older Hillersden soils show more distinct indications of increased soil weathering with subsoil base saturation values that are 20% of those in the surface horizons, cation exchange values that are 50% of those in the topsoils and anion storage values that are approximately twice those of the surface horizons. Renwick soils, in keeping with a somewhat younger age than the Hillersden soils have average base saturation and anion storage values that are lower than those for Hillersden soils. The wetter soils (Wairau mottled, Spring Creek and Broadbridge) show evidence in their soil chemistry of the influence of drainage waters with higher subsoil base saturation values and also low Olsen P values.

There is little that stands out with respect to the values for the heavy metals, although average values for Hillersden soils are slightly greater than those for the Renwick soils and this perhaps is a reflection of some input of sediments from rocks on the north side of the Wairau River.

Soil Physical Characteristics

Soil physical conditions were assessed using bulk density, particle density and water release characteristics which in turn were used to calculate total soil porosity, air capacity and macroporosity. The results of the soil physical analyses are given in Table A2 (Appendix 1). Soil profile descriptions provide information on parent material, soil age or soil weathering depth and drainage and are provided in Appendix B.

3.5. Middle Wairau Valley Soils Overview

The soils that were examined and sampled are grouped into the following categories: Awatere family (3), Wairau family (3) Wairau mottled (1) Spring Creek family (2), Omaka family (5), Hillersden family (7), Renwick family (7), Broadbridge family (5), Marama family (2) and the Jordan family (1).

3.5.1. Awatere soil

The first discrete terrace (high floodplain surface) is 1-2m above the current floodplain surface and is most likely inundated during floods with a return period of the order of 30-100 years. This terrace has a strongly braided surface with the thickness of fine material and the degree of soil stoniness varying between the former channels and the risers. Awatere soils (sites 4, 12, 33) are formed on these surfaces.

They have weakly developed soil profiles without subsoil oxidation and structure development and buried topsoils may be present. These soils are probably the equivalent of the Upper Wairau series of Harris and Birrell (1939) who describe the soil as being subject to frequent flooding.

Figure 2. A high floodplain surface on which the Awatere family of soils occur.

The soil physical and chemical properties for the Awatere family soils sampled are given in Table 1. The Awatere soils are well drained, moderately deep to deep soils with a rapid permeability. Topsoil textures are silty or sandy loams. Subsoils are sandy loams. Soil structure is weakly developed in this family.

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 Anion Storage Capacity for the Awatere soil was classed as low. ASC (commonly referred to as Phosphate Retention) is a measure of the ability of the soil to remove anions (including phosphorus) from solution, holding onto it firmly, tending to make it 'slowly' available to plants. Low P-retention values indicate that plants will give a better response to the same amount of phosphate fertiliser than those plants on a soil with high P-retention.

Topsoil cadmium concentrations were approximately background concentrations found in soils (0.16 mg/kg; Roberts, Longhurst and Brown. 1994). None of the sampled sites had cadmium levels exceeding the suggested 0.6 mg/kg trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils (MAF, 2011).

Cation exchange capacity (CEC) is a measure of the soils ability to hold and exchange nutrients with the soil solution and plant roots. The CEC of the Awatere soil family is classed as medium. This has implications when considering the amount of fertiliser to apply. Low CEC soils are unable to hold as much nutrient as a high CEC soil.

Table 1. Soil properties for the Awatere family of soils

Overview	
Family:	Awatere
Soil Classification:	Typic Fluvial Recent
Parent material origin:	Greywacke Alluvium

Average Physical properties	
Texture:	Silty/sandy loam
Potential rooting depth:	>100cm
Soil depth:	Moderately deep and Deep
Drainage class:	Well
Permeability:	Rapid
Topsoil stones:	Stoneless
0-30cm Plant Available Water	75mm (range 69– 79mm)
0-60cm Plant Available Water	126mm (range 113 – 135mm)
Topsoil bulk density:	0.92 g/cm3
Subsoil bulk density:	1.14 g/cm3
Average Chemical properties	
Topsoil organic matter:	3.7%
Topsoil ASC (P retention):	20%
Topsoil cadmium:	0.11 mg/kg
Soil pH:	6.2
Topsoil cation exchange capacity:	15.8 me/100g

3.5.2. Wairau soil

The soils of this grouping (sites 10, 11.18) occur above the floodplain on a surface that is again uneven and braided with the pattern of old channels and risers associated with soils that vary from shallow extremely bouldery to deep (>100cm to underlying gravel) with loamy to sandy textures. The soil profiles typically are well drained, have weak soil structures, inconspicuous or only slight subsoil oxidation with brownish to olive brown colours and overlie un-oxidised gravel or sandy gravel.

Soil physical and chemical properties for the Wairau family soils sampled are given in Table 2.

Figure 3. An uneven floodplain surface on which the Wairau family of soils occur.

Total available water was calculated for both the 0-30cm and 0-60cm soil depths. For both soil depths storage capacity was classed as high.

The average topsoil ASC for the Wairau soil was classed as low. However, a large range of values was found during testing.

Topsoil cadmium concentrations were approximately background concentrations (0.16 mg/kg) found in soils (Roberts et al. 1994). None of the sampled sites had cadmium levels exceeding the suggested 0.6 mg/kg trigger value outlined in the national strategy for managing risks caused by cadmium in agricultural soils (MAF, 2011).

Cation exchange capacity (CEC) is a measure of the soils ability to hold and exchange nutrients with the soil solution and plant roots. The CEC of the Wairau soil family is classed as Medium.

Table 2. Soil properties for the Wairau family of soils

Overview	
Family:	Wairau
Soil Classification:	Weathered Fluvial Recent
Parent material origin:	Greywacke Alluvium
Average Physical properties	
Texture:	Silt loams
Potential rooting depth:	40-60cm
Soil depth:	Deep
Drainage class:	Well drained
Permeability:	Rapid

Topsoil stones:	Slightly stony
0-30cm Plant Available Water	68mm (range 59mm to 78mm)
0-60cm Plant Available Water	109 mm (range 93mm to 129mm)
Topsoil bulk density:	0.85 g/cm3
Subsoil bulk density:	0.98 g/cm3
Average Chemical properties	
Topsoil organic matter:	5.3% Range 6.7% to 3.9%
Topsoil ASC (P retention):	Low (24%) Range 31% to <15%
Topsoil cadmium:	0.119 mg/kg
Soil pH:	6.05
Cation exchange capacity:	17.4 me/100g

3.5.3. Wairau mottled soils

This name (soil site 1) is provisionally given for recent alluvial soils within the low terrace system that have impeded drainage. The name derives from separations made by Laffan and Vincent (1990) in the lower Wairau Valley. Wairau mottled soils are restricted to low lying areas or former river channels where runoff water or spring fed flows are found. The main features of this soil are weak soil development to <45cm with subsoil mottling at greater depth and colour patterns that conform with a drainage status class of moderately well drained to imperfectly drained. This soil is probably the equivalent of the Upper Wairau meadow phase as described by Harris and Birrell (1939).

Figure 4. A low terrace surface on which the Wairau mottled soils occur.

Some soil physical and chemical properties for the single Wairau mottled soil found in the study are given in Table 3.

Total available water was calculated for both the 0-30cm and 0-60cm soil depths. For both soil depths storage capacity was classed as high.

Topsoil ASC for the Wairau mottled soil was classed as low. Topsoil cadmium concentrations were approximately background concentrations. The CEC of the Wairau mottled family is classed as medium.

Table 3. Average soil properties for the Wairau mottled family of soils

Overview	
Family:	Wairau mottled
Soil Classification:	Mottled Fluvial Recent
Parent material origin:	Greywacke alluvium
Average Physical properties	
Texture:	Sandy loam
Potential rooting depth:	65cm
Soil depth:	Deep
Drainage class:	Imperfectly drained
Permeability:	Moderate
Topsoil stones:	Stoneless
0-30cm Plant Available Water	73mm
0-60cm Plant Available Water	128mm
Topsoil bulk density:	0.89 g/cm3
Subsoil bulk density:	0.99 g/cm3
Average Chemical properties	
Topsoil organic matter:	5.2%
Topsoil ASC (P retention):	Low (<15%)
Topsoil cadmium:	0.19 mg/kg
Soil pH:	5.8
Cation exchange capacity:	18 me/100g

3.5.4. Spring Creek soils

This name is also given provisionally for soils (site 9, 22) on the low terrace system that are poorly drained. It comes from separations made by Laffan and Vincent (1990) in the lower Wairau Valley for soils on recent alluvium that are poorly drained. These soils may also have been included in the Upper Wairau meadow phase as described by Harris and Birrell (1939). The main features are reddish topsoil mottles and light grey and strong brown subsoil mottles throughout the subsoil, the proportion and position of which define its status as poorly drained. The weathering profile is shallow and extends to around 45cm depth. Areas of these soils are likely to be found in small patches in lower-lying former

overflow channels, as well as in some backslope locations that are influenced by subsurface drainage discharges from adjacent small hillside gullies and valleys.

Figure 5. A low terrace surface on which the Spring Creek family of soils occur.

Some average soil physical and chemical properties for the two Spring Creek soils sampled are given in Table 4. Typically, these soils are shallow with poor drainage and slow permeability.

Total available water was calculated for both the 0-30cm and 0-60cm soil depths. For both soil depths storage capacity was classed as high.

Topsoil ASC for the Spring Creek soil was classed as low. Cation exchange capacity for this soil is classed as medium.

Average topsoil cadmium concentrations were approximately typical background concentrations found in soils (Roberts et al. 1994). One topsoil sample was 0.24 mg/kg probably indicating high or recent phosphate fertiliser application. The source of cadmium is most likely phosphate fertiliser which has been shown to contain cadmium as an incidental impurity.

Table 4. Average soil properties for the Spring Creek family of soils

Overview	
Family:	Spring Creek
Soil Classification:	Typic Orthic Gley
Parent material origin:	greywacke alluvium
Average Physical properties	
Texture:	Sandy silt
Potential rooting depth:	55cm
Soil depth:	Moderate
Drainage class:	Imperfect

Permeability:	Slow
Topsoil stones:	Slightly stony
0-30cm Plant Available Water	84mm (range 82 – 85mm)
0-60cm Plant Available Water	124mm (range 113 – 135mm)
Topsoil bulk density:	0.79 g/cm3
Subsoil bulk density:	0.98 g/cm3
Average Chemical properties	
Topsoil organic matter:	7.4%
Topsoil ASC (P retention):	Low (29%)
Topsoil cadmium:	0.16 mg/kg
Soil pH:	5.8
Cation exchange capacity:	19.5 me/100g

3.5.5. Omaka soils

Soils of this grouping (sites 15,16,17,32,36) appear to cover a significant proportion of the upper surfaces of the low terrace system. The ground surface is somewhat more uniform with less pronounced braided channelling although the extent of surface stoniness is still very variable and there are some extensive areas of extremely bouldery soils. The principle features of this group of soils are a more distinctive subsoil weathering zone with browner colours, strong to moderate development of topsoil and subsoil structures and a weathering depth that on average, extends to about 50cm depth before passing into paler coloured little weathered material. Soil textures are predominantly silt loam, grading into sandy loam or sand with depth. Omaka soils are well drained with soil depth classes varying from shallow and extremely stony to moderately deep (45-100cm to gravel) and deep (>100cm to gravel).

Figure 6. A lowland terrace surface on which the Omaka family of soils occur.

The average soil physical and chemical properties for the five Omaka family soils sampled are given in Table 5. The widely ranging values reflect the variable nature of this family of soils. Total available water for both the 0-30cm and 0-60cm soil depths was classed as high.

Topsoil ASC for the Omaka soil ranges from medium to high dependant on soil texture. Topsoil CEC shows less variation but still ranges from 16 to 26 meq/100g (medium) across the sites sampled. Average topsoil cadmium concentrations were approximately typical background concentrations found in soils.

Table 5. Average soil properties for the Omaka family of soils

Overview	
Family:	Omaka
Soil Classification:	Weathered Orthic Recent
Parent material origin:	Greywacke alluvium
Average Physical properties	
Texture:	Silty loam, Sandy loam
Potential rooting depth:	45 - 65cm
Soil depth:	Deep
Drainage class:	Well drained
Permeability:	Rapid
Topsoil stones:	Stoneless, slightly stony
0-30cm Plant Available Water	68mm (range 61 – 76mm)
0-60cm Plant Available Water	116mm (range 96 – 125mm)

Topsoil bulk density:	0.82 g/cm3
Subsoil bulk density:	0.93 g/cm3
Average Chemical properties	
Topsoil organic matter:	4.9 – 10.3%
Topsoil ASC (P retention):	Low to High (21 to 74%)
Topsoil cadmium:	0.15 mg/kg
Soil pH:	5.9
Cation exchange capacity:	20.3 me/100g

3.5.6. Hillersden soils

This name is retained, (rather than the generalised Hororata set name) for the soils within this group (sites 2,3,5,8,13,19,28) occurring on the uppermost terrace that formed as a result of extensive aggradation of gravels resulting from the outwash of sediment following glacial retreat in Late Otiran time. Towards the eastern end of middle Wairau Valley, there are several discrete steps on this surface but they were unable to be traced into the western part of the valley. Hillersden soils are distinguished by topsoils and subsoils with strongly to moderately developed structure, by yellowish brown to dark yellowish brown subsoil colours and a weathering zone that extends to around 70cm depth or greater. Texture in the upper horizons is predominantly silt loam and passes to sandy loam and coarse sand at depth. The soil depth was found to vary from shallow and very stony to moderately deep (45-100cm to underlying gravel). The soils at site 3 and 13 were situated on the upper level of the Speargrass Formation surface and both of these soils appeared slightly more weathered than the other Hillersden soils that were sampled.

Figure 7. A upper terrace surface on which the Hillersden family of soils occur.

Average soil physical and chemical properties for the seven Hillersden family soils sampled are given in Table 6. Total available water for both the 0-30cm and 0-60cm soil depths was classed as high.

Topsoil ASC for the Hillersden soils measured ranged from 25% to 65% with the average value at 39%. Phosphate retention can vary depending on local soil conditions such as soil pH, organic matter content, types of clay present and how weathered the soils are.

Average topsoil cadmium concentrations were higher than typical background concentrations found in soils but not markedly so. This is probably a reflection of historical use of phosphate fertiliser on these soil types.

Table 6. Average soil properties for the Hillersden family of soils

Overview	
Family:	Hillersden
Soil Classification:	Orthic Brown
Parent material origin:	Greywacke alluvium
Average Physical properties	
Texture:	Silt loam
Potential rooting depth:	45 to 65cm
Soil depth:	Deep
Drainage class:	Well drained
Permeability:	Rapid
Topsoil stones:	Slightly stony
0-30cm Plant Available Water	71mm (range 56 – 88mm)
0-60cm Plant Available Water	127mm (range 97 – 156mm)
Topsoil bulk density:	0.79 g/cm3
Subsoil bulk density:	0.89 g/cm3
Chemical properties	
Topsoil organic matter:	5.9 – 14.7%
Topsoil ASC (P retention):	Range low to high (25 to 65%)
Topsoil cadmium:	0.19 mg/kg
Soil pH:	5.8
Cation exchange capacity:	20.7 me/100g

3.5.7. Renwick soils

Included in this group (sites 7,20,26,27,29,31,34) are the soils that are formed on the fan surfaces that are formed within and at the mouths of the numerous gullies and small streams that discharge from the

southern hills onto the valley floor surface. In the initial survey of the soils by Harris and Birrell (1939), all of the middle Wairau Valley soils on the intermediate Speargrass deposit surface and including the fan sediments from the tributary gullies were called Hillersden soils, apart from a small area identified as Briary soils (the basis for that separation is unclear). In the survey of the lower Wairau by Laffan and Vincent (1990), well drained soils of the southern tributary valleys were mapped as Renwick soils.

The fan sediments in and at the mouths of the tributary gullies are a distinct lithological unit derived from erosion within adjacent hills, rather than from glacial outwash as in the Speargrass Formation. As these sediments form fans on the Speargrass Formation surface and sometimes spill out onto the terrace surface below, they clearly post-date the Speargrass Formation deposits.

Renwick soils were found to have coarse material (predominantly medium subangular stones) throughout their profiles with underlying very stony gravel at depths between 25-65cm. The soil weathering depth is approximately 65cm with the subsoil colour predominantly yellowish brown, passing into light olive brown towards the base of the weathering zone. Soil structure is for the most part moderately developed and texture is silt loam in upper horizons passing into sandy loam or sand at depth.

Figure 8. A lowland fan surface on which the Renwick family of soils occur.

Table 7 shows average soil properties for the seven Renwick family soils sampled. Total available water was calculated for both the 0-30cm and 0-60cm soil depths. For both soil depths storage capacity was classed as high.

Topsoil ASC for the Renwick soil family was classed as low for all samples. Cation exchange capacity is classed as medium for all samples. Two sites showed average topsoil cadmium concentrations above background concentrations found in soils. The source is likely phosphate fertiliser which has been shown to contain cadmium as an incidental impurity.

Table 7. Average soil properties for the Renwick family of soils

Overview	
Family:	Renwick
Soil Classification:	Immature Orthic Brown

Parent material origin:	Greywacke colluvium
Average Physical properties	
Texture:	Silt Loam
Potential rooting depth:	45 - 65cm
Soil depth:	Deep
Drainage class:	Well Drained
Permeability:	Moderate to rapid
Topsoil stones:	Moderately stony
0-30cm Plant Available Water	80mm (range 54 – 105mm)
0-60cm Plant Available Water	120mm (range 79 – 154mm)
Topsoil bulk density:	0.84 g/cm3
Subsoil bulk density:	0.98 g/cm3
Chemical properties	
Topsoil organic matter:	4.5 – 12.5%
Topsoil ASC (P retention):	Low (24%)
Topsoil cadmium:	0.16 mg/kg
Soil pH:	6.1
Cation exchange capacity:	18.4 me/100g

3.5.8. Broadbridge soils

In the survey by Harris and Birrell (1939), soils associated with Renwick series and which had poor drainage were identified as Renwick heavy phase, while in the Lower Wairau survey by Laffan and Vincent (1990), imperfectly drained soils associated with Renwick series were separated as Broadbridge series. Within this group (sites 6,23,25,30,35) are soils that are formed from fine textured colluvial sediments deposited on the terrace surfaces near the base of the side valley fans and they are included with Broadbridge soils. The soils occur on flat to gently sloping surfaces, have clayey textures with moderately developed blocky structure, which in some cases pass into moderately developed prismatic structure at depth. The subsoils are strongly mottled, with the mixtures and proportions of grey and reddish brown or strong brown colours indicating their drainage status as imperfectly and poorly drained. The soil depths were found to vary from shallow (<45cm to gravel) to moderately deep (85cm+).

Figure 9. A lowland fan surface on which the Broadbridge family of soils occur.

Some average soil physical and chemical properties for the five Broadbridge family soils sampled are given in Table 8. Total available water was calculated for both the 0-30cm and 0-60cm soil depths. For both soil depths storage capacity was classed as high.

Topsoil ASC values for these soils range widely. One site recorded a Low P retention value (<15%) with the remaining 4 sites having Medium levels between 30 to 60%.

CEC values varied between Medium to High. This may be a result of elevated organic matter levels found in these soils when compared with other soil families of this area.

Average topsoil cadmium concentrations were similar to background concentrations.

Table 8. Average soil properties for the Broadbridge family of soils

Overview	
Family:	Broadbridge
Soil Classification:	Fragic Pallic
Parent material origin:	Greywacke alluvium / colluvium
Average Physical properties	
Texture:	Silt loam to clay
Potential rooting depth:	35 - 65cm
Soil depth:	Shallow to moderately deep
Drainage class:	Imperfectly drained
Permeability:	Slow
Topsoil stones:	Stoneless

0-30cm Plant Available Water	85mm (range 61 – 105mm)
0-60cm Plant Available Water	125mm (range 93 – 153mm)
Topsoil bulk density:	0.75 g/cm3
Subsoil bulk density:	1.0 g/cm3
Chemical properties	
Topsoil organic matter:	5.2 - 11.6%
Topsoil ASC (P retention):	>15% (Low) to 52% (High)
Topsoil cadmium:	0.16 mg/kg
Soil pH:	5.7
Cation exchange capacity:	28 me/100g

3.5.9. Marama soils

This group (sites 21,24) includes the soils that were sampled on the alluvial deposits, which are associated with the incipient streams and drainage channels that flow across the intermediate terrace. The name given is provisional, as this soil-landscape unit has not previously been separated in Wairau Valley, however soil profile 24 resembles soils that were separated on stream alluvium in Awatere Valley as Marama soils (Campbell 2007).

The two soils that were sampled are somewhat different from each other. At site 21 the soil on a stream floodplain has a thin layer of alluvium from recent flooding, overlying buried topsoil, which forms part of an older, probably former Omaka soil. At site 24, the sampled soil is from a weakly defined stream terrace and displays stronger development, with yellowish brown to light olive brown subsoil colours and moderately developed soil structure.

Soils from stream alluvium on the terrace surfaces may not be extensive, but as illustrated by the two sites sampled, are likely to be quite variable and do form part of the pattern of soils found within Middle Wairau Valley.

Figure 10. A intermediate terrace surface on which the Marama family of soils occur.

Only two Marama soils are noted in this survey and the average soil physical and chemical properties for are given in Table 9

Total available water was calculated for both the 0-30cm and 0-60cm soil depths and is classed as high.

The two sites recorded very different P retention figures. Site 21 was found to be <15% (low) for topsoil. Site 24 reported Medium (35% and 40%) for both topsoil samples from this site.

CEC is reported as Medium for both sites.

Average topsoil cadmium concentrations showed marked variation with site 21 showing levels well below background concentrations and Site 24 well above possibly as a result of phosphate fertiliser use.

Table 9. Average soil properties for the Marama family of soils

Overview	
Family:	Marama
Soil Classification:	Immature Pallic
Parent material origin:	Greywacke stream alluvium
Average Physical properties	
Texture:	Silt loam
Potential rooting depth:	50 cm
Soil depth:	Moderate
Drainage class:	Well drained
Permeability:	Rapid
Topsoil stones:	Slightly stony
0-30cm Plant Available Water	66mm (range 59 – 74mm)
0-60cm Plant Available Water	101mm (range 91 – 110mm)
Topsoil bulk density:	0.83 g/cm3
Subsoil bulk density:	0.89 g/cm3
Chemical properties	
Topsoil organic matter:	4.8 - 6.6%
Topsoil ASC (P retention):	Medium (30%) (range >15% to 40%)
Topsoil cadmium:	0.27 mg/kg (range 0.19 to 0.43)
Soil pH:	5.8
Cation exchange capacity:	19 me/100g

3.5.10. Jordan soils

In the survey of Awatere, Kaikoura and Marlborough Counties (Gibbs and Beggs 1953), as well as the South Island 4 mile to the inch mapping (Soil Bureau Staff 1968) an area of predominantly hilly land (but which included some old dissected terrace land) from near the Wye to the Branch Rivers, was separated as Kahutara hill soils. Elsewhere, Jordan soils have been mapped on old terrace surfaces that were loess mantled. Jordan soils were also identified in the Awatere Valley survey by Campbell (2007) on old loess covered terrace surfaces and on similar old terrace surfaces in the Lower Wairau Plains survey (Omaka Valley) by Laffan and Vincent (1990).

Only one site representative of the older terrace landscape unit (site 14) was sampled in this investigation and the soil conforms to the Jordan soil type as mapped elsewhere. This old terrace landform occurs somewhat intermittently through middle Wairau Valley and it forms part of the foothills terrain rather than standing out as a prominent terrace entity. The ground surface is predominantly undulating and the extent of dissection, sometimes by small gullies from the adjacent hills, illustrates the extent to which erosion has occurred since the terrace gravels were deposited. The surface material overlying the gravel is loess, windblown sediment derived from the gravelly outwash surfaces during late glacial times.

The soil at site 14 has silt loam to heavy silt loam texture through the profile, has distinct subsoil mottling that increases in intensity with depth where the mottle pattern then assumes a layered horizontal appearance. Dark grey clay/organic material forms part of the complex mottle pattern. Soil structure in the upper subsoil is coarse blocky but becomes prismatic below the area of most intense mottling while the subsoil strength is hard to very hard.

Figure 11. A foothills terrain surface on which the Jordan family of soils occur.

The soil physical and chemical properties for the single Jordan family soil sampled are given in Table 10. Total available water was classed as high for both the 0-30cm and 0-60cm soil depths. Topsoil phosphate retention and cation exchange capacity for this soil are both classed as low. Topsoil cadmium concentrations were approximately typical background concentrations.

Table 10. Average soil properties for the Jordan family of soils

Overview	
Family:	Jordan
Soil Classification:	Argillic Duric Pallic
Parent material origin:	Loess over gravel

Average Physical properties	
Texture:	Silt loam
Potential rooting depth:	>55cm
Soil depth:	Moderate
Drainage class:	Moderately well drained
Permeability:	Moderate
Topsoil stones:	Stoneless
0-30cm Plant Available Water	93mm (single site assessed)
0-60cm Plant Available Water	149mm (single site assessed)
Topsoil bulk density:	0.8 g/cm3
Subsoil bulk density:	1.04 g/cm3
Chemical properties	
Topsoil organic matter:	6.8%
Topsoil ASC (P retention):	Low (18%)
Topsoil cadmium:	0.13 mg/kg
Soil pH:	6.0
Cation exchange capacity:	16.5 me/100g

4. Discussion

The examination of Middle Wairau Valley soils along the series of transects showed that there is a general uniformity in the soil pattern through this part of Wairau Valley, the main differences relating to the land surface geological history, as represented by construction of the various terrace surfaces. The soils show a distinct progression in soil development from the lowest to the highest terraces, as reflected in increases in the weathering depth from negligible in the youngest soils (Awatere), to around 70cm in the oldest soils (Hillersden). These morphological differences are also reflected in the chemical properties of the soils. However, within this relatively straight-forward geomorphic context, the soil patterns are complicated by variations in stoniness and soil depth, by additions of sediments from the hills and valleys to the south and by the influence of drainage waters in places.

The soil textural and depth variability (stoniness and depth of fine sediment over gravel) are a function of past fluvial conditions in the Wairau River, with former high energy flows, in places giving rise to extensive areas of very bouldery surfaces. The addition of sediments from the numerous valleys to the south together with the construction of small fans has resulted in a pattern of stony soils on the upper fan surfaces and in places, deeper and finer textured soils at the toe positions of the fans. Drainage waters from the side valleys which emerge on the lower fan surfaces have given rise in places to soils with impeded drainage. These drainage waters in places form small streams that flow across the upper terrace surface resulting in patches of soils that are formed from reworked sediments.

Although the Wairau Fault is a major tectonic feature in middle Wairau Valley, there is little indication that it has any significant impact on the soil pattern, apart from some local areas of soils with impeded drainage through the emergence of springs, or through the accumulation of water in down-warped areas.

On the higher terrace remnants on the southern margin of the valley, the soils there are formed from loessial materials and have somewhat different physical and chemical properties.

Soils that have been identified in the traverses are correlated with other soils recognised within the area. Some Soil names used in earlier 1:250 000 surveys are of too general a nature to convey useful information for detailed use purposes.

The soil landscape model outlined here could probably be used as the basis for undertaking soil mapping at a more detailed scale, sometime in the future. If detailed soil mapping in middle Wairau Valley were to occur it would result in a greater subdivision of the soils, however this would require additional resources that are outside the scope of this report.

5. Summary

- Ten soil families were identified in the Wairau Valley i.e. Awatere, Wairau, Wairau mottled, Spring Creek, Omaka, Hillersden, Renwick, Broadbridge, Marama and Jordon soils.
- The Awatere, Wairau, Wairau mottled and Omaka families of soils, occur on the lower terrace systems of the valley floor. The intermediate terraces are occupied by older Hillersden and Broadbridge soils. Renwick soils occupy fan surfaces that have outwashed from adjacent hills to the south of the valley floor. Spring Creek soils can be found in low or intermediate terrace areas that are poorly drained. Marama soils occupy sites that are formed by small local streams and their nearby terraces. Jordon soils occupy a single loess-covered, foothills location.
- The Awatere, Wairau, Wairau mottled, Omaka, Hillersden, Renwick, Marama, Jordon soils (29 sites), were generally well or moderately drained with moderately rapid permeability and have high water storage capacities. These properties make the soils generally lower risk in terms of direct losses from land application of effluent because of their ability to store and treat effluent.
- The Broadbridge and Spring creek soils (7 sites) were poorly or imperfectly drained, slow to moderately slow permeability and have high water storage capacities. These properties make the soils generally higher risk in terms of direct losses from land application of effluent because of their slow rate of drainage and permeability.
- The soil sampling work in this project is at a large scale to provide a general overview of the range of soil properties likely to be encountered but further detailed site specific work would be required on a farm scale for use in determining best practice for effluent discharge and irrigation. 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 permeability's and should be done on site specific basis when categorising the soil for effluent or irrigation application.

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Appendix A – Soil Analysis Tables

Table A1 Soil chemical analysis from soil sampling pits

Site	Soil Family	Depth	pH	Olsen P	ASC	Avail. N	OM	Total C	Total N	C/N	K	Ca	Mg	Na	BS K	BS Ca	BS Mg	BS Na	Total BS	CEC	Vol.Wt
				mg/L	%	kg/ha	%	%	%		me/100g	me/100g	me/100g	me/100g	%BS	%BS	%BS	%BS	%	me/100g	g/mL
Site 1	Wairau Mottled	0-7.5cm	5.8	10	< 15	89	5.2	3	0.25	12.3	0.38	9.6	1.43	0.21	2.1	53	7.9	1.2	65	18	0.86
Site 1	Wairau Mottled	0-20cm	6.3	2	< 15	109	3.7	2.1	0.2	10.8	0.16	8.9	0.91	0.09	1.1	64	6.6	0.6	73	14	0.92
Site 1	Wairau Mottled	30-37.5cm	5.9	1	< 15	39	1.6	0.9	0.08	11	0.06	4.1	1.84	0.17	0.7	45	20	1.8	67	9	0.99
Site 2	Hillersden	0-7.5cm	6.1	21	32	193	9.1	5.3	0.47	11.1	0.64	13.4	0.7	0.09	2.8	59	3.1	0.4	66	23	0.84
Site 2	Hillersden	0-20cm	5.9	12	44	139	6.9	4	0.37	10.9	0.19	9.1	0.41	0.07	1	47	2.1	0.4	50	20	0.92
Site 2	Hillersden	30-40cm	5.4	22	65	15	3.6	2.1	0.15	13.9	0.11	1.7	0.09	0.07	1	14	0.7	0.6	17	12	0.93
Site 3	Hillersden	0-7.5cm	5.9	13	29	195	6.6	3.8	0.36	10.5	0.24	11	0.65	0.08	1.2	54	3.2	0.4	58	20	0.82
Site 3	Hillersden	0-20cm	5.6	7	41	129	4.3	2.5	0.24	10.5	0.17	6.6	0.32	< 0.05	1	39	1.9	0.3	42	17	0.91
Site 3	Hillersden	30-40cm	5.2	6	62	15	1.5	0.9	0.05	16.7	0.09	1.6	0.14	< 0.05	0.7	13	1.1	0.3	15	12	0.94
Site 4	Awatere	0-7.5cm	6	15	17	135	6.5	3.8	0.39	9.8	0.71	10.7	1.8	0.26	3.6	54	9.1	1.3	68	20	0.79
Site 4	Awatere	0-20cm	5.8	7	23	54	5.4	3.1	0.23	13.6	0.46	8.7	1.63	0.23	2.5	47	8.8	1.3	60	18	0.81
Site 4	Awatere	30-40cm	6.1	3	< 15	43	1.4	0.8	0.09	9.6	0.07	2.9	1.18	0.11	1	41	16.6	1.5	60	7	1.04
Site 5	Hillersden	0-7.5cm	5.4	24	39	176	8.9	5.2	0.48	10.8	0.61	7.3	0.68	0.08	2.9	35	3.2	0.4	42	21	0.74
Site 5	Hillersden	0-20cm	5.3	13	45	135	6.7	3.9	0.38	10.3	0.23	4.8	0.36	0.11	1.3	26	2	0.6	30	18	0.77
Site 5	Hillersden	23-33cm	5	10	67	40	3.3	1.9	0.15	12.4	0.1	0.6	0.06	< 0.05	0.8	5	0.5	0.3	7	13	0.86
Site 6	Broadbridge	0-7.5cm	5.5	12	47	291	8.4	4.9	0.5	9.7	0.57	14.9	2.98	1.15	1.7	44	8.8	3.4	58	34	0.7
Site 6	Broadbridge	0-20cm	5.3	13	52	243	6.8	4	0.4	9.8	0.5	14.1	2.5	2.61	1.6	45	8	8.4	63	31	0.83
Site 6	Broadbridge	25-35cm	6.1	11	41	98	1.4	0.8	0.11	7.7	0.39	11.6	2.28	7.06	1.5	45	8.9	27.7	84	26	1.08
Site 7	Renwick	0-7.5cm	6.9	20	28	136	6.8	3.9	0.37	10.7	0.44	10.7	1.59	0.07	2.8	69	10.2	0.4	82	16	0.91
Site 7	Renwick	0-20cm	6.7	8	29	106	4.5	2.6	0.24	10.8	0.15	9.8	0.84	0.11	1	68	5.8	0.8	76	14	0.86
Site 7	Renwick	30-40cm	5.8	3	29	< 10	1	0.6	0.05	12.4	0.07	3.4	0.19	0.06	0.8	40	2.2	0.7	43	9	1.13

Site	Soil Family	Depth	pH	Olsen P	ASC	Avail. N	OM	Total C	Total N	C/N	K	Ca	Mg	Na	BS K	BS Ca	BS Mg	BS Na	Total BS	CEC	Vol.Wt
				mg/L	%	kg/ha	%	%	%		me/100g	me/100g	me/100g	me/100g	%BS	%BS	%BS	%BS	%	me/100g	g/mL
Site 8	Hillersden	0-7.5cm	6.9	16	35	156	7	4	0.37	10.9	0.69	12.3	1.82	0.16	3.7	65	9.7	0.9	80	19	0.78
Site 8	Hillersden	0-20cm	6	10	45	124	5.9	3.4	0.3	11.6	0.23	6.9	0.97	0.12	1.3	39	5.5	0.7	47	18	0.8
Site 8	Hillersden	25-35cm	5.3	5	67	38	2	1.2	0.09	13.1	0.08	2.3	0.13	0.07	0.6	19	1.1	0.6	21	12	0.88
Site 9	Spring Creek	0-7.5cm	5.5	9	27	194	8.1	4.7	0.42	11.2	0.66	6.8	1.63	0.18	3.5	36	8.6	1	49	19	0.78
Site 9	Spring Creek	0-20cm	5.6	5	19	132	6.1	3.5	0.3	11.7	0.24	6	1.4	0.12	1.5	36	8.5	0.7	47	16	0.8
Site 9	Spring Creek	22-32cm	6.2	< 1	20	< 10	1.3	0.8	0.06	13.2	0.08	6.1	2.17	0.19	0.6	45	15.8	1.4	62	14	0.97
Site 10	Wairau	0-7.5cm	5.9	27	28	146	5.4	3.1	0.3	10.3	0.23	7.9	0.46	0.09	1.4	47	2.7	0.5	52	17	0.86
Site 10	Wairau	0-20cm	6.1	26	31	120	5.3	3.1	0.22	13.9	0.22	8.2	0.47	0.1	1.3	50	2.8	0.6	54	17	0.86
Site 10	Wairau	18-28cm	6.1	11	56	57	4.4	2.6	0.18	14.3	0.13	4.4	0.18	0.08	1	33	1.3	0.6	36	13	0.87
Site 11	Wairau	0-7.5cm	5.7	19	15	199	6.7	3.9	0.36	10.9	0.38	10.6	1.47	0.06	1.7	49	6.7	0.3	57	22	0.75
Site 11	Wairau	0-20cm	5.7	6	25	146	3.9	2.3	0.24	9.7	0.26	7.3	1	< 0.05	1.5	41	5.6	0.2	49	18	0.88
Site 11	Wairau	27-37cm	5.7	13	20	51	2.2	1.3	0.13	10.3	0.16	3.2	0.63	< 0.05	1.6	31	6.1	0.4	39	10	0.95
Site 12	Awatere	0-7.5cm	6.1	7	< 15	99	6	3.5	0.25	13.9	0.2	9.6	1.16	0.05	1.2	58	7	0.3	67	17	0.91
Site 12	Awatere	0-20cm	6.2	3	< 15	102	3.4	2	0.18	11.2	0.14	8.9	0.82	< 0.05	1	64	5.9	0.4	71	14	0.99
Site 12	Awatere	25-35cm	6.5	2	< 15	38	1.2	0.7	0.06	11.6	0.07	4.2	0.66	< 0.05	1	58	9.1	0.6	69	7	1.12
Site 13	Hillersden	0-7.5cm	5.5	23	34	194	11.1	6.5	0.48	13.5	0.89	9.5	0.83	0.06	3.7	40	3.5	0.3	47	24	0.76
Site 13	Hillersden	0-20cm	5.1	23	45	124	6.1	3.5	0.29	12	1.63	3.8	0.45	< 0.05	8.1	19	2.2	0.1	29	20	0.84
Site 13	Hillersden	20-32cm	4.9	29	67	48	4	2.3	0.22	10.6	0.73	0.8	0.12	< 0.05	4.8	6	0.8	0.2	11	15	0.89
Site 14	Jordan	0-7.5cm	6.1	6	15	254	7.8	4.5	0.48	9.4	0.42	9.1	1.06	0.11	2.3	50	5.8	0.6	59	18	0.73
Site 14	Jordan	0-20cm	5.8	7	22	215	5.9	3.4	0.4	8.6	0.23	5.5	0.79	0.11	1.6	37	5.4	0.8	45	15	0.87
Site 14	Jordan	25-35cm	5.5	1	35	61	1	0.6	0.06	10.6	0.1	1.9	0.58	0.22	1	18	5.5	2.1	27	10	1.04
Site 15	Omaka	0-7.5cm	6	14	32	230	7.7	4.5	0.42	10.5	0.7	10.8	1.07	0.08	3.3	50	5	0.4	59	21	0.79
Site 15	Omaka	0-20cm	5.4	8	40	163	6.4	3.7	0.33	11.4	0.79	7.8	0.59	< 0.05	4.4	43	3.3	0.2	51	18	0.86
Site 15	Omaka	24-34cm	5	41	62	< 10	1.7	1	0.08	11.5	0.09	0.9	0.14	< 0.05	0.9	9	1.4	0.3	12	10	0.95

Site	Soil Family	Depth	pH	Olsen P	ASC	Avail. N	OM	Total C	Total N	C/N	K	Ca	Mg	Na	BS K	BS Ca	BS Mg	BS Na	Total BS	CEC	Vol.Wt
				mg/L	%	kg/ha	%	%	%		me/100g	me/100g	me/100g	me/100g	%BS	%BS	%BS	%BS	%	me/100g	g/mL
Site 16	Omaka	0-7.5cm	6.2	21	45	198	10.1	5.9	0.48	12.2	0.4	14.3	1.04	0.06	1.5	55	4	0.2	61	26	0.73
Site 16	Omaka	0-20cm	5.7	7	74	123	6.7	3.9	0.32	12.3	0.16	5.2	0.56	< 0.05	0.9	27	3	0.2	31	19	0.85
Site 16	Omaka	20-30cm	5.6	2	84	10	2.6	1.5	0.09	15.9	0.06	< 0.5	0.09	< 0.05	0.7	5	1	0.2	7	9	0.92
Site 17	Omaka	0-7.5cm	6.6	11	29	176	8	4.7	0.39	12.1	0.6	13.7	2.29	0.06	2.6	59	9.9	0.3	72	23	0.78
Site 17	Omaka	0-20cm	6.3	8	36	149	4.9	2.9	0.32	9.1	0.39	10.1	1.46	0.05	2	52	7.4	0.3	61	20	0.92
Site 17	Omaka	28-38cm	5.5	7	56	50	2.4	1.4	0.1	14	0.1	3	0.42	0.08	0.7	21	3	0.5	25	14	0.94
Site 18	Wairau	0-7.5cm	6.6	11	20	145	6.3	3.7	0.34	10.9	0.53	10.2	1.36	0.06	3.2	60	8	0.3	72	17	0.84
Site 18	Wairau	0-20cm	6.2	4	29	114	5	2.9	0.23	12.5	0.17	7.4	0.91	0.05	1.2	50	6.2	0.4	58	15	0.88
Site 18	Wairau	26-36cm	5.7	4	37	39	1.6	1	0.1	9.1	0.07	1.8	0.22	< 0.05	0.8	21	2.6	0.5	25	8	1.11
Site 19	Hillersden	0-7.5cm	6.2	12	22	222	9.5	5.5	0.52	10.5	0.36	12.2	0.55	0.06	1.8	63	2.8	0.3	68	20	0.79
Site 19	Hillersden	0-20cm	6.3	8	33	185	7.6	4.4	0.38	11.7	0.27	11.3	0.22	< 0.05	1.5	63	1.2	0.2	66	18	0.84
Site 19	Hillersden	25-35cm	5.6	9	72	16	2.7	1.5	0.12	13.3	0.1	1.4	< 0.04	< 0.05	0.9	13	0.2	0.3	14	11	0.93
Site 20	Renwick	0-7.5cm	6.3	30	26	264	12.5	7.2	0.69	10.4	0.64	14.7	0.91	0.08	2.7	62	3.8	0.3	69	24	0.82
Site 20	Renwick	0-20cm	5.8	10	27	200	8.4	4.9	0.48	10.1	0.35	11.3	0.29	0.06	1.8	57	1.5	0.3	60	20	0.82
Site 20	Renwick	27-37cm	5.5	35	56	71	4.8	2.8	0.23	12	0.14	2.1	0.04	< 0.05	1.2	18	0.3	0.2	20	12	0.96
Site 21	Marama	0-7.5cm	6.5	16	< 15	157	6.6	3.8	0.34	11.2	0.51	15.8	1.11	0.06	2.4	75	5.2	0.3	82	21	0.8
Site 21	Marama	0-20cm	6	13	15	137	4.9	2.9	0.25	11.5	0.93	9.1	1.08	0.07	5.5	54	6.5	0.4	67	17	0.9
Site 21	Marama	40-50cm	5.8	3	32	58	2.4	1.4	0.1	14.7	0.27	8	0.9	< 0.05	1.7	50	5.6	0.3	58	16	0.89
Site 22	Spring Creek	0-7.5cm	6.2	11	24	280	8.9	5.1	0.43	12	0.34	13.7	0.98	0.23	1.5	61	4.4	1	68	22	0.77
Site 22	Spring Creek	0-20cm	5.9	6	37	164	6.8	4	0.3	13.3	0.22	9.7	0.64	0.16	1.1	47	3.1	0.8	52	21	0.82
Site 22	Spring Creek	22-32cm	6	6	52	43	2	1.2	0.09	13.6	0.05	3	0.24	0.08	0.5	32	2.5	0.8	36	9	0.99
Site 23	Broadbridge	0-7.5cm	5.7	12	29	329	11.6	6.7	0.53	12.8	0.61	21.3	3.89	0.19	1.7	58	10.7	0.5	71	36	0.67
Site 23	Broadbridge	0-20cm	6	9	33	265	7.7	4.5	0.45	10	0.66	20.5	4.05	0.2	1.9	60	11.9	0.6	75	34	0.76
Site 23	Broadbridge	30-40 cm	6.2	2	16	62	1.8	1	0.07	14	0.12	9.2	2.73	0.23	0.8	58	17.2	1.5	78	16	0.99
Site 24	Marama	0-7.5cm	6.2	37	35	226	6.2	3.6	0.35	10.3	1.32	9.9	2.06	0.08	6.6	49	10.2	0.4	66	20	0.81
Site 24	Marama	0-20cm	6.2	20	40	148	4.8	2.8	0.27	10.5	0.36	8.6	1.88	0.06	2	47	10.4	0.3	60	18	0.83
Site 24	Marama	22-32 cm	5.2	5	61	41	1.4	0.8	0.06	12.9	0.1	2.4	0.42	0.07	0.8	18	3.3	0.5	23	13	0.9

Site	Soil Family	Depth	pH	Olsen P	ASC	Avail. N	OM	Total C	Total N	C/N	K	Ca	Mg	Na	BS K	BS Ca	BS Mg	BS Na	Total BS	CEC	Vol.Wt
				mg/L	%	kg/ha	%	%	%		me/100g	me/100g	me/100g	me/100g	%BS	%BS	%BS	%BS	%	me/100g	g/mL
Site 25	Broadbridge	0-7.5cm	5.8	16	24	298	11.5	6.6	0.54	12.4	0.95	15.9	3.98	0.15	3.1	52	13.1	0.5	69	30	0.74
Site 25	Broadbridge	0-17cm	5.9	4	32	190	8.2	4.8	0.4	12	0.45	15.6	4.19	0.23	1.6	55	14.6	0.8	71	29	0.8
Site 25	Broadbridge	17-27 cm	6.3	2	16	61	1.6	0.9	0.1	8.6	0.21	7.4	2.81	0.23	1.5	53	20.2	1.7	76	14	1.07
Site 26	Renwick	0-7.5cm	5.6	11	16	195	6.8	4	0.4	9.9	0.39	7.2	0.96	0.07	2.4	44	5.9	0.4	53	16	0.77
Site 26	Renwick	0-18cm	5.1	6	23	155	5.6	3.3	0.31	10.4	0.56	6.1	0.69	< 0.05	3.7	41	4.7	0.3	50	15	0.87
Site 26	Renwick	21-31 cm	5.3	5	45	42	1.2	0.7	0.06	11.8	0.11	3.2	0.24	< 0.05	0.9	26	1.9	0.3	29	12	1.04
Site 27	Renwick	0-7.5cm	6.1	15	18	195	8.4	4.9	0.49	9.9	0.31	12	1.1	0.09	1.5	57	5.2	0.4	64	21	0.73
Site 27	Renwick	0-20cm	5.9	6	25	159	5.4	3.2	0.35	9	0.15	9.9	0.41	< 0.05	0.8	53	2.2	0.2	56	19	0.8
Site 27	Renwick	22-32 cm	5.5	27	63	< 10	2	1.2	0.09	13.1	0.08	2.1	0.11	< 0.05	0.7	18	1	0.2	20	11	0.89
Site 28	Hillersden	0-7.5cm	5.7	25	49	207	14.7	8.5	0.61	13.9	0.69	14.5	0.73	0.09	2.3	49	2.4	0.3	54	30	0.65
Site 28	Hillersden	0-17cm	5.4	11	65	162	11.8	6.8	0.44	15.4	0.17	5.7	0.1	< 0.05	0.7	24	0.4	< 0.1	25	23	0.69
Site 28	Hillersden	20-30 cm	5.4	4	84	23	3.3	1.9	0.17	11.2	0.09	0.6	< 0.04	< 0.05	0.8	5	0.3	0.2	6	11	0.8
Site 29	Renwick	0-7.5cm	6.2	10	< 15	259	7.3	4.2	0.39	11	0.83	13	1.08	0.06	4	63	5.2	0.3	72	21	0.88
Site 29	Renwick	0-16cm	6.3	5	18	206	6.4	3.7	0.32	11.7	0.28	12.7	1.16	0.08	1.6	71	6.5	0.5	79	18	0.8
Site 29	Renwick	22-32 cm	5.7	14	61	44	1.5	0.9	0.1	8.7	0.08	4	0.74	0.15	0.6	30	5.5	1.1	37	13	0.9
Site 30	Broadbridge	0-7.5cm	6.1	4	< 15	260	9.4	5.5	0.47	11.7	0.48	11.6	1.09	0.07	2.3	56	5.3	0.3	64	21	0.74
Site 30	Broadbridge	0-18cm	6	3	< 15	209	8.3	4.8	0.38	12.7	0.21	10.5	0.78	0.09	1.1	52	3.9	0.4	57	20	0.76
Site 30	Broadbridge	23-33 cm	5.3	< 1	51	60	1.6	0.9	0.11	8.6	0.1	1.6	0.33	0.06	0.7	12	2.5	0.5	16	14	0.96
Site 31	Renwick	0-7.5cm	6.5	6	18	232	9.1	5.2	0.57	9.2	0.36	12.8	0.7	< 0.05	1.8	65	3.5	0.2	70	20	0.84
Site 31	Renwick	0-17cm	6	7	32	120	7.3	4.3	0.39	10.9	0.17	6.9	0.41	< 0.05	1.1	43	2.6	0.2	47	16	0.88
Site 31	Renwick	25-35cm	6	30	76	64	4.8	2.8	0.21	13.2	0.16	4.1	0.09	0.05	1.1	29	0.7	0.4	31	14	0.87
Site 32	Omaka	0-7.5cm	5.9	8	22	157	10.3	5.9	0.33	18.3	0.47	11.8	1.13	0.06	2	50	4.8	0.2	57	24	0.73
Site 32	Omaka	0-20cm	5.5	8	46	141	5	2.9	0.28	10.4	0.45	6.1	0.53	< 0.05	2.4	33	2.8	0.2	38	18	0.88
Site 32	Omaka	25-35 cm	5.4	6	54	57	1.9	1.1	0.08	13.4	0.2	1.6	0.08	< 0.05	1.8	14	0.7	0.3	17	11	0.9
Site 33	Awatere	0-7.5cm	6.3	9	< 15	133	5.1	3	0.31	9.7	0.81	8.5	1.71	< 0.05	5.3	56	11.2	0.3	73	15	0.96
Site 33	Awatere	0-20cm	6.1	2	< 15	70	3.4	2	0.17	11.6	0.25	5	1.56	< 0.05	2.3	47	14.6	0.3	64	11	1.04
Site 33	Awatere	21-31 cm	6.3	2	< 15	14	0.7	0.4	0.06	6.9	0.07	3.8	1.35	< 0.05	1	49	17.8	0.5	69	8	1.26

Site	Soil Family	Depth	pH	Olsen P	ASC	Avail. N	OM	Total C	Total N	C/N	K	Ca	Mg	Na	BS K	BS Ca	BS Mg	BS Na	Total BS	CEC	Vol.Wt
				mg/L	%	kg/ha	%	%	%		me/100g	me/100g	me/100g	me/100g	%BS	%BS	%BS	%BS	%	me/100g	g/mL
Site 34	Renwick	0-7.5cm	5.8	21	22	204	8.6	5	0.44	11.3	0.56	11.4	0.64	0.07	2.8	58	3.3	0.3	64	20	0.85
Site 34	Renwick	0-20cm	5.7	11	28	189	7.2	4.1	0.4	10.4	0.2	9.5	0.43	0.08	1.1	52	2.4	0.4	56	18	0.87
Site 34	Renwick	30-40 cm	5.5	12	61	15	1.2	0.7	0.13	5.7	0.11	2	0.06	0.06	1	20	0.6	0.6	22	10	1.07
Site 35	Broadbridge	0-7.5cm	5.5	8	36	279	9.2	5.3	0.48	11.1	0.54	7.9	1.67	0.08	2.2	32	6.8	0.3	41	25	0.66
Site 35	Broadbridge	0-20cm	5.6	5	39	197	5.2	3	0.36	8.4	0.31	7.5	1.3	0.07	1.5	37	6.3	0.3	45	21	0.83
Site 35	Broadbridge	23-33cm	5.6	2	59	105	3.3	1.9	0.15	12.8	0.13	3.6	1.45	0.14	0.7	19	7.7	0.7	28	19	0.89
Site 36	Omaka	0-7.5cm	5.7	9	21	205	7.2	4.2	0.36	11.6	0.47	7.2	0.83	< 0.05	2.7	41	4.8	0.2	49	18	0.78
Site 36	Omaka	0-20cm	5.1	8	39	164	4.9	2.9	0.29	9.7	0.16	4.5	0.53	< 0.05	1	29	3.4	0.3	34	16	0.87
Site 36	Omaka	26-36 cm	5.3	5	54	24	1.8	1	0.07	13.9	0.06	1.2	0.24	0.06	0.6	11	2.2	0.5	14	11	0.96

Abbreviations:
ASC – Anion Storage capacity (estimated) Also known as P retention
Avail. N – Available N (15 cm depth)
OM – Organic Matter
C/N – Carbon to Nitrogen ratio
BS – Base Saturation
CEC – Cation Exchange Capacity
Vol. Wt – Volume Weight.

Table A2 Soil physical analysis from soil sampling pits

									FC					PWP		
Site	Soil name	Depth	Volume Stones	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air filled Porosity	Volumetric water content						RAW	PAW
									5kPa	10kPa	20kPa	40kPa	100kPa	1500kPa		
		(cm)	%	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 1 top	Wairau mottled	0 - 7.5		1.18	2.60	54.5	11.0	13.4	43.5	41.1	39.1	37.5	35.8	16.7	5.3	24.4
Site 1 sub	Wairau mottled	30 - 37.5		1.66	2.71	38.7	4.0	7.3	34.7	31.4	29.4	26.9	22.5	13.0	8.9	18.5
Site 2 top	Hillersden	0 - 7.5		1.13	2.58	56.4	13.9	16.6	42.4	39.8	37.9	36.4	35.3	18.1	4.5	21.7
Site 2 sub	Hillersden	30 - 37.5		1.33	2.66	50.2	9.1	12.1	41.0	38.1	35.3	33.1	30.0	19.9	8.1	18.2
Site 3 top	Hillersden	0 - 7.5		1.20	2.58	53.6	7.7	11.6	45.9	42.0	40.0	38.3	36.6	18.7	5.4	23.3
Site 3 sub	Hillersden	30 - 37.5		1.40	2.67	47.8	9.6	11.9	38.2	35.9	33.8	32.0	29.7	22.5	6.2	13.5
Site 4 top	Awatere	0 - 7.5		1.18	2.58	54.3	2.5	4.3	51.8	50.0	48.4	47.3	45.8	24.3	4.2	25.7
Site 4 sub	Awatere	30 - 37.5		1.54	2.70	42.8	8.4	12.5	34.4	30.3	28.2	26.0	23.9	12.5	6.3	17.8
Site 5 top	Hillersden	0 - 7.5		1.00	2.55	60.8	14.8	16.2	46.0	44.6	42.4	40.7	38.2	17.0	6.4	27.6
Site 5 sub	Hillersden	23 - 30.5		1.13	2.65	57.4	17.1	20.4	40.3	37.0	34.2	31.8	28.8	17.5	8.2	19.5
Site 6 top	Broadbridge	0 - 7.5		0.99	2.49	60.2	7.2	10.0	53.0	50.2	48.4	46.8	44.9	30.0	5.3	20.1
Site 6 sub	Broadbridge	22 - 29.5		1.35	2.74	50.7	<1	1.0	50.5	49.7	48.9	47.6	45.1	34.4	4.6	15.3
Site 7 top	Renwick	0 - 7.5		1.32	2.60	49.1	10.6	13.1	38.5	36.0	34.4	32.8	31.0	18.0	5.0	18.0
Site 7 sub	Renwick	27 - 34.5		1.69	2.68	36.8	3.8	5.6	33.1	31.2	30.3	29.3	27.7	15.7	3.5	15.4
Site 8 top	Hillersden	0 - 7.5		1.30	2.60	50.1	5.4	5.9	44.7	44.2	42.6	41.1	39.8	21.9	4.4	22.3
Site 8 sub	Hillersden	23 - 30.5		1.41	2.66	47.2	5.6	7.5	41.6	39.7	37.9	36.3	33.7	22.2	6.0	17.5
Site 9 top	Spring Creek	0 - 7.5		1.02	2.55	60.2	9.9	15.4	50.3	44.8	42.4	40.4	37.7	16.5	7.1	28.2
Site 9 sub	Spring Creek	22 - 29.5		1.69	2.67	36.8	2.7	4.0	34.1	32.8	31.7	30.7	29.3	22.4	3.5	10.3
Site 10 top	Wairau	0 - 7.5		1.42	2.60	45.5	<1	2.5	45.3	43.0	41.0	39.7	38.7	21.7	4.3	21.3
Site 10 sub	Wairau	13 - 20.5		1.37	2.62	47.9	4.8	9.1	43.1	38.8	37.1	35.7	33.9	21.8	4.9	17.0
Site 11 top	Wairau	0 - 7.5		1.20	2.57	53.4	9.7	11.9	43.7	41.5	39.8	38.5	37.8	17.8	3.7	23.6
Site 11 sub	Wairau	27 - 34.5		1.51	2.67	43.6	14.7	16.5	28.9	27.1	25.5	24.0	22.5	16.0	4.5	11.1

									FC					PWP		
Site	Soil name	Depth	Volume Stones	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air filled Porosity	Volumetric water content						RAW	PAW
									5kPa	10kPa	20kPa	40kPa	100kPa	1500kPa		
		(cm)	%	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 12 top	Awatere	0 - 7.5		1.22	2.63	53.5	7.2	12.1	46.3	41.4	39.1	36.5	33.7	15.2	7.7	26.3
Site 12 sub	Awatere	25 - 32.5		1.46	2.70	46.1	14.8	18.1	31.3	28.0	25.1	21.6	18.0	9.3	10.1	18.7
Site 13 top	Hillersden	0 - 7.5		1.03	2.53	59.4	22.0	24.4	37.4	35.0	33.3	31.9	30.2	16.2	4.8	18.8
Site 13 sub - rep. 1	Hillersden	20 - 32	33	1.36	2.6	48.4	4.3	5.7	44.1	42.7	42.0	40.6	38.5	23.7	4.2	19
Site 14 top	Jordan	0 - 7.5		1.03	2.55	59.7	12.8	16.7	46.9	43.0	39.9	37.7	34.4	11.9	8.6	31.0
Site 14 sub	Jordan	20 - 27.5		1.43	2.66	46.1	11.7	14.6	34.3	31.5	29.1	25.8	22.0	13.1	9.5	18.5
Site 15 top	Omaka	0 - 7.5		1.12	2.53	55.9	9.7	12.8	46.2	43.1	40.7	38.2	36.1	18.4	7.0	24.7
Site 15 sub	Omaka	24 - 31.5		1.40	2.68	47.9	5.3	9.7	42.5	38.2	35.8	33.2	30.8	21.8	7.4	16.4
Site 16 top	Omaka	0 - 7.5		1.01	2.48	59.3	10.8	13.4	48.5	45.9	43.7	41.7	39.9	23.1	6.0	22.8
Site 16 sub	Omaka	18 - 25.5		1.14	2.65	57.0	9.9	13.1	47.1	43.9	40.9	38.8	35.9	22.7	7.9	21.2
Site 17 top	Omaka	0 - 7.5		1.11	2.53	56.2	8.2	10.7	47.9	45.5	43.1	41.0	39.0	20.3	6.5	25.2
Site 17 topvine	Omaka	0 - 7.5		1.09	2.57	57.4	14.7	17.0	42.7	40.4	38.3	36.3	35.0	20.0	5.5	20.4
Site 17 sub	Omaka	28 - 35.5		1.47	2.66	44.9	5.9	7.7	39.0	37.2	35.5	34.0	31.2	23.5	6.0	13.8
Site 18 top	Wairau	0 - 7.5		1.30	2.59	49.7	4.0	6.5	45.7	43.2	40.7	38.2	35.5	17.3	7.8	25.9
Site 18 topvine	Wairau	0 - 7.5		1.33	2.61	49.2	10.2	12.3	38.9	36.9	35.0	32.9	30.6	17.1	6.3	19.8
Site 18 sub	Wairau	26 - 33.5		1.41	2.69	47.7	17.6	20.9	30.1	26.8	23.7	21.4	18.9	14.2	7.9	12.6
Site 19 top	Hillersden	0 - 7.5		0.98	2.53	61.5	14.3	17.9	47.1	43.6	40.8	38.7	35.8	14.2	7.7	29.3
Site 19 sub	Hillersden	24 - 31.5		1.27	2.66	52.1	7.8	12.0	44.4	40.1	36.3	32.9	29.0	19.6	11.1	20.5
Site 20 top	Renwick	0 - 7.5		1.04	2.54	58.9	13.7	16.8	45.2	42.1	39.5	37.3	35.6	12.3	6.4	29.8
Site 20 sub - rep. 1	Renwick	25 - 36	33	1.11	2.6	57.7	20.2	24.0	37.5	33.7	31.0	29.0	26.5	16.1	7.2	17.6
Site 20 sub - rep. 2	Renwick	25 - 36	33	1.11	2.6	57.9	20.1	24.2	37.8	33.7	30.9	28.8	26.6	16.1	7.1	17.6

									FC					PWP		
Site	Soil name	Depth	Volume Stones	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air filled Porosity	Volumetric water content						RAW	PAW
									5kPa	10kPa	20kPa	40kPa	100kPa	1500kPa		
		(cm)	%	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 21 top	Marama	0 - 7.5		1.19	2.60	54.3	9.2	10.8	45.1	43.5	41.6	39.8	38.5	18.9	5.0	24.6
Site 21 sub	Marama	40 - 47.5		1.38	2.67	48.5	12.2	14.1	36.3	34.4	32.8	31.2	30.0	22.2	4.4	12.2
Site 22 top	Spring Creek	0 - 7.5		0.83	2.54	67.5	19.2	21.7	48.3	45.8	43.3	40.9	39.2	18.4	6.6	27.3
Site 22 sub	Spring Creek	22 - 29.5		1.39	2.67	48.1	8.8	10.8	39.3	37.3	35.4	33.3	29.8	20.7	7.5	16.6
Site 23 top	Broadbridge	0 - 7.5		0.91	2.48	63.2	<1	1.0	63.9	62.2	59.2	56.7	54.7	30.7	7.4	31.5
Site 23 sub	Broadbridge	30 - 37.5		1.61	2.69	40.2	2.7	3.8	37.5	36.4	35.3	34.4	33.1	25.4	3.4	11.0
Site 24 top	Marama	0 - 7.5		1.22	2.58	52.8	8.1	10.0	44.7	42.8	41.4	39.8	38.5	23.3	4.4	19.6
Site 24 sub	Marama	22 - 29.5		1.54	2.69	42.8	4.0	5.2	38.8	37.6	36.5	35.4	33.6	26.9	4.0	10.7
Site 25 top	Broadbridge	0 - 7.5		0.86	2.49	65.3	<1	3.3	64.7	62.0	58.8	56.5	55.1	27.1	6.9	34.9
Site 25 sub	Broadbridge	20 - 27.5		1.56	2.66	41.3	2.5	4.1	38.8	37.2	35.6	34.1	32.2	21.2	5.0	15.9
Site 26 top	Renwick	0 - 7.5		1.16	2.56	54.8	1.2	3.2	53.6	51.6	49.2	46.6	44.8	16.7	6.8	34.9
Site 26 sub	Renwick	21 - 28.5		1.48	2.66	44.4	8.4	10.0	36.0	34.4	32.7	31.1	28.6	18.5	5.8	16.0
Site 27 top	Renwick	0 - 7.5		1.15	2.57	55.1	3.8	5.3	51.3	49.8	47.7	45.0	41.4	15.9	8.4	33.9
Site 27 sub	Renwick	22 - 29.5		1.34	2.67	49.6	7.8	10.2	41.9	39.4	37.2	34.8	32.3	23.0	7.1	16.4
Site 28 top	Hillersden	0 - 7.5		0.98	2.43	59.9	7.6	11.2	52.2	48.7	45.9	43.8	41.2	25.9	7.6	22.8
Site 28 sub	Hillersden	20 - 27.5		1.09	2.64	58.8	9.9	12.7	48.9	46.1	43.6	40.5	36.9	23.6	9.2	22.5
Site 29 top	Renwick	0 - 7.5		1.02	2.53	59.8	16.2	19.1	43.6	40.7	38.1	35.5	31.1	14.9	9.6	25.7
Site 29 sub	Renwick	22 - 29.5		1.48	2.65	44.0	7.7	9.0	36.4	35.0	33.7	32.5	30.5	24.9	4.5	10.1
Site 30 top	Broadbridge	0 - 7.5		1.06	2.51	57.7	9.2	12.0	48.5	45.7	43.1	40.5	37.9	16.3	7.8	29.3
Site 30 sub	Broadbridge	23 - 30.5		1.46	2.64	44.9	7.0	8.8	37.9	36.1	34.5	32.3	29.3	23.4	6.8	12.7
Site 31 top	Renwick	0 - 7.5		1.20	2.61	54.1	9.9	13.8	44.2	40.3	37.8	35.7	34.7	15.5	5.6	24.8
Site 31 sub - rep. 1	Renwick	25 - 35	46	1.25	2.7	53.2	6.3	9.9	46.9	43.3	41.6	40.1	38.4	26.6	4.9	16.7
Site 31 sub - rep. 2	Renwick	25 - 35	46	1.26	2.7	52.8	6.0	9.7	46.7	43.1	41.1	39.6	38.3	26.9	4.8	16.2

									FC					PWP		
Site	Soil name	Depth	Volume Stones	Dry Bulk Density	Particle Density	Total Porosity	Macro Porosity	Air filled Porosity	Volumetric water content						RAW	PAW
									5kPa	10kPa	20kPa	40kPa	100kPa	1500kPa		
		(cm)	%	(t/m3)	(t/m3)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)	(%, v/v)
Site 32 top	Omaka	0 - 7.5		1.02	2.53	59.9	15.3	17.2	44.6	42.7	41.2	39.8	37.9	20.6	4.9	22.1
Site 32 sub	Omaka	25 - 32.5		1.40	2.66	47.3	6.5	8.8	40.8	38.5	36.6	34.7	32.9	22.0	5.7	16.5
Site 33 top	Awatere	0 - 7.5		1.43	2.66	46.4	7.5	10.0	39.0	36.4	33.9	32.5	30.8	13.5	5.6	22.9
Site 33 sub	Awatere	21 - 28.5		1.46	2.71	46.3	16.2	24.8	30.1	21.5	16.1	12.7	10.3	6.8	11.2	14.7
Site 34 top	Renwick	0 - 7.5		1.27	2.55	50.1	11.7	13.9	38.4	36.2	34.2	32.6	30.8	16.6	5.4	19.6
Site 34 sub	Renwick	32 - 39.5	>10	2.67	64.8	33.1	35.9	31.7	28.9	26.7	25.1	23.1	9.3	5.8	19.6	19.6
Site 35 top	Broadbridge	0 - 7.5		0.93	2.52	63.0	14.2	16.4	48.8	46.6	44.5	43.3	41.9	20.2	4.7	26.3
Site 35 sub	Broadbridge	23 - 30.5		1.42	2.69	47.3	8.8	10.8	38.5	36.5	34.7	33.0	31.3	25.6	5.2	10.8
Site 36 top	Omaka	0 - 7.5		1.17	2.58	54.6	14.1	17.0	40.5	37.6	35.9	34.0	31.7	17.1	5.9	20.5
Site 36 sub	Omaka	26 - 33.5		1.61	2.68	39.9	3.9	5.3	36.0	34.6	33.2	31.7	29.8	22.9	4.8	11.7

Abbreviations:

FC – Field Capacity

PWP – Permanent Wilting Point

RAW – Readily Available Water

PAW – Plant Available Water (also referred to as Total Available Water

Notes:

1. Macro-porosity cited here is determined between total porosity and tension of -5 kPa, for consistency with the National Soils Database of New Zealand (NSD).
2. Air Filled-porosity cited here is determined between total porosity and tension of -10 kPa. This can be referred to as Macro-porosity. It is important to be aware what tension has been used, particularly with historical or NSD data.
3. Macroporosity (and Air-filled porosity) figures marked as <1 indicate instances where the samples were right on the limit of the methodology capability. These samples have extremely low macro porosity and have presented as negative numbers following calculation of the raw data. In reality it is impossible for MacroPorosity to exceed Total Porosity hence the macroporosity data has been adjusted to simply indicate samples with extremely low figures.

4. For Site 13 sub, Site 20 sub and Site 31 sub, dual replicate bulk samples were collected and a volume replacement technique was employed due to high stone content. In the laboratory whole-soil bulk density, stone volume and the fine-earth bulk density were calculated. The calculated fine-earth bulk density was used as a target to pack re-constituted cores with fine-earth material. These were then analysed for moisture release. Note that the re-constituted sample for Site 13 sub rep. 2 collapsed, hence no moisture release results are reported. It was found that the core sample for Site 34 sub had greater than 10% stones by volume. Results were re-calculated for that sample to account for the presence of stones in the core sample.
5. Plant Available Water for the 30 and 60 cm depths was calculated for each soil sample. These data where then averaged for soil family and is reported in the text as millimetres of Plant Available Water. PAW values for individual samples can be calculated using the values in Table A2. The calculations for this are:
    - Percent Plant Available Water (%PAW) is calculated by subtracting PWP from FC using the % v/v values in Table A2:

$$VWC_{10kPa\ v/v} - VWC_{1500kPa\ v/v} = \%PAW$$

    - % PAW is converted to mm water per 75mm sample:

$$\frac{75mm\ \times \%PAW}{100} = mm\ water\ per\ sample$$

    - mm water/ sample was then converted to mm/30cm and mm/60cm by dividing by 75 and multiplying by the relevant final depth. It is assumed that the 75mm sample is representative of the entire 30cm depth.

$$\frac{mm\ water\ per\ sample}{75mm} \times \frac{300mm}{10mm\ per\ cm} = Plant\ avalible\ water\ per\ 30cm\ depth$$

    - These values were then rated for low, medium or high PAW using the following scale:

	PAW mm per 100 cm depth	**PAW mm per 60cm depth**
Low	0 - 59mm	0-34mm
Medium	60 - 149mm	35 – 89mm
High	150mm and greater	90mm or greater

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

Site	Soil Family	Depth	'Total' Zinc	'Total' Copper	'Total' Chromium	'Total' Arsenic	'Total' Lead	'Total' Nickel	'Total' Mercury	'Total' Cadmium
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Site 1	Wairau Mottled	0-7.5cm	48	8	24	2.9	10.1	30	0.05	0.19
Site 1	Wairau Mottled	0-20cm	49	7	23	3.8	11.4	32	0.05	0.13
Site 1	Wairau Mottled	30-37.5cm	50	11	19.9	3.9	12.3	45	0.09	0.04
Site 2	Hillersden	0-7.5cm	53	5	22	2.5	11.5	12.7	0.04	0.28
Site 2	Hillersden	0-20cm	54	5	18.6	2.9	12.8	14.1	0.03	0.15
Site 2	Hillersden	30-40cm	58	5	23	3.3	13.5	21	0.05	0.04
Site 3	Hillersden	0-7.5cm	54	8	26	2.6	10.1	17.2	0.03	0.2
Site 3	Hillersden	0-20cm	57	6	21	2.7	10.7	13.2	0.03	0.15
Site 3	Hillersden	30-40cm	54	6	25	2.6	11.2	15.8	0.06	0.04
Site 4	Awatere	0-7.5cm	65	12	23	3.7	15.7	27	0.05	0.17
Site 4	Awatere	0-20cm	67	13	35	2.9	14.6	29	0.07	0.16
Site 4	Awatere	30-40cm	51	7	24	2.7	12.3	36	0.06	0.03
Site 5	Hillersden	0-7.5cm	66	5	18.6	2.9	12.7	13.7	0.03	0.24
Site 5	Hillersden	0-20cm	60	5	17.9	2.6	12.4	12.6	0.03	0.19
Site 5	Hillersden	23-33cm	51	5	16.1	2.8	11.9	12.8	0.06	0.05
Site 6	Broadbridge	0-7.5cm	65	9	21	4.9	25	12.3	0.06	0.17
Site 6	Broadbridge	0-20cm	64	9	27	5.2	26	14.7	0.06	0.15
Site 6	Broadbridge	25-35cm	88	9	27	9	30	15.9	0.11	0.03
Site 7	Renwick	0-7.5cm	68	10	14.8	2	9.4	12.1	0.04	0.14
Site 7	Renwick	0-20cm	57	6	16.1	1.9	8.1	12	0.04	0.14
Site 7	Renwick	30-40cm	43	100	13.8	2.2	9.5	10	0.03	0.03
Site 8	Hillersden	0-7.5cm	63	7	27	2.9	12.2	18	0.04	0.17
Site 8	Hillersden	0-20cm	55	5	23	2.7	11.5	16	0.04	0.11
Site 8	Hillersden	25-35cm	52	6	21	3.5	13.5	16.7	0.06	0.03
Site 9	Spring Creek	0-7.5cm	42	< 4	20	1.9	9.5	13.2	0.03	0.14
Site 9	Spring Creek	0-20cm	37	< 4	19.4	2	9.3	13.2	0.03	0.09
Site 9	Spring Creek	22-32cm	39	< 4	24	2.6	11.8	14	0.05	< 0.02
Site 10	Wairau	0-7.5cm	56	5	22	3.4	12.9	17.8	0.03	0.17
Site 10	Wairau	0-20cm	53	5	23	2.9	11.9	18.9	0.04	0.16
Site 10	Wairau	18-28cm	58	5	24	3.9	14	22	0.06	0.06
Site 11	Wairau	0-7.5cm	53	6	23	1.6	11.6	14.7	0.02	0.17
Site 11	Wairau	0-20cm	53	5	20	1.4	12.8	15.4	0.05	0.12
Site 11	Wairau	27-37cm	56	7	23	1.9	12.8	24	0.06	0.05
Site 12	Awatere	0-7.5cm	51	7	24	3.8	11.9	28	0.05	0.18
Site 12	Awatere	0-20cm	51	9	21	3.5	11.7	32	0.07	0.17
Site 12	Awatere	25-35cm	49	10	20	3.7	11.3	46	0.08	0.05
Site 13	Hillersden	0-7.5cm	57	5	21	2.5	10.9	13.8	0.03	0.22
Site 13	Hillersden	0-20cm	59	6	24	3	12.9	14.8	0.04	0.15
Site 13	Hillersden	20-32cm	67	6	24	3	13.9	16.5	0.05	0.07

Site	Soil Family	Depth	'Total' Zinc	'Total' Copper	'Total' Chromium	'Total' Arsenic	'Total' Lead	'Total' Nickel	'Total' Mercury	'Total' Cadmium
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Site 14	Jordan	0-7.5cm	24	< 4	10.7	1.2	5.6	7	0.03	0.13
Site 14	Jordan	0-20cm	23	< 4	12.1	1.4	6.2	7.3	0.03	0.13
Site 14	Jordan	25-35cm	27	< 4	16.8	1.7	7.2	9.6	0.05	0.03
Site 15	Omaka	0-7.5cm	45	8	21	2.6	10.8	15.2	0.03	0.12
Site 15	Omaka	0-20cm	45	8	19.5	2.6	11.1	14.7	0.03	0.12
Site 15	Omaka	24-34cm	56	6	22	3.2	13.1	23	0.04	0.03
Site 16	Omaka	0-7.5cm	49	7	23	2.6	11.8	13	0.04	0.2
Site 16	Omaka	0-20cm	49	6	21	2.9	12.9	11.4	0.06	0.1
Site 16	Omaka	20-30cm	60	6	24	3.2	13.8	16.7	0.09	0.04
Site 17	Omaka	0-7.5cm	60	12	18.5	3.4	12.7	13.7	0.06	0.23
Site 17	Omaka	0-20cm	62	9	20	3.3	12.7	14.6	0.06	0.17
Site 17	Omaka	28-38cm	64	8	17.5	3	15.3	13.8	0.11	0.03
Site 18	Wairau	0-7.5cm	43	8	26	3.4	8.2	23	0.02	0.16
Site 18	Wairau	0-20cm	41	5	19	2.7	7.9	20	0.02	0.12
Site 18	Wairau	26-36cm	51	7	27	3.4	11.6	40	0.04	0.04
Site 19	Hillersden	0-7.5cm	41	5	16.5	2	6.6	10.3	0.02	0.22
Site 19	Hillersden	0-20cm	43	6	14.5	2.3	7.9	8.9	0.03	0.21
Site 19	Hillersden	25-35cm	57	6	18.2	3	11.2	12.7	0.07	0.06
Site 20	Renwick	0-7.5cm	43	6	12.2	1.8	6.7	8.1	0.03	0.27
Site 20	Renwick	0-20cm	47	5	14.5	2.7	7.2	8.9	0.03	0.26
Site 20	Renwick	27-37cm	59	5	16.9	2	7.3	10.9	0.04	0.09
Site 21	Marama	0-7.5cm	61	10	21	3.4	13.9	14.7	0.07	0.22
Site 21	Marama	0-20cm	60	9	17.4	3	13	12.5	0.07	0.19
Site 21	Marama	40-50cm	72	10	24	3	15.7	17	0.12	0.08
Site 22	Spring Creek	0-7.5cm	47	7	20	2.1	10.7	14.9	0.05	0.24
Site 22	Spring Creek	0-20cm	48	5	17.1	2.3	11.4	13.1	0.06	0.16
Site 22	Spring Creek	22-32cm	59	6	27	3	12.5	21	0.07	0.03
Site 23	Broadbridge	0-7.5cm	64	12	27	2.5	15.6	16.1	0.1	0.18
Site 23	Broadbridge	0-20cm	69	11	19.9	3	17.3	13.3	0.11	0.14
Site 23	Broadbridge	30-40 cm	39	4	14.3	3	13.7	8.3	0.09	0.03
Site 24	Marama	0-7.5cm	61	16	24	3	13.5	13.7	0.06	0.43
Site 24	Marama	0-20cm	57	12	18.8	3.4	14	14.8	0.06	0.25
Site 24	Marama	22-32 cm	56	8	21	3.5	15	14.6	0.13	0.03
Site 25	Broadbridge	0-7.5cm	62	12	12.8	2.1	13.2	10	0.09	0.16
Site 25	Broadbridge	0-17cm	57	11	18.5	2.8	14.4	13.6	0.11	0.13
Site 25	Broadbridge	17-27 cm	43	6	14.7	1.9	11.2	9.7	0.09	0.03
Site 26	Renwick	0-7.5cm	34	11	13.8	2.2	8.3	7.5	0.02	0.14
Site 26	Renwick	0-18cm	36	11	11.6	2.2	7.7	6.6	0.02	0.11
Site 26	Renwick	21-31 cm	41	6	13.4	2.5	10.2	8.8	0.05	0.03
Site 27	Renwick	0-7.5cm	46	9	15.2	2	8.4	9.9	0.04	0.19
Site 27	Renwick	0-20cm	41	7	13.5	2	8.7	8.9	0.05	0.19
Site 27	Renwick	22-32 cm	60	8	19.1	3.1	13.5	15.7	0.12	0.03

Site	Soil Family	Depth	'Total' Zinc	'Total' Copper	'Total' Chromium	'Total' Arsenic	'Total' Lead	'Total' Nickel	'Total' Mercury	'Total' Cadmium
			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Site 28	Hillersden	0-7.5cm	46	7	16.8	2.6	12.3	10.1	0.05	0.26
Site 28	Hillersden	0-17cm	54	7	23	2.6	14.1	12.7	0.06	0.2
Site 28	Hillersden	20-30 cm	70	8	25	3.7	18.1	20	0.14	0.04
Site 29	Renwick	0-7.5cm	35	8	16.7	1.8	7.6	9.7	0.04	0.13
Site 29	Renwick	0-16cm	29	6	17.2	1.7	5.8	9.2	0.06	0.1
Site 29	Renwick	22-32 cm	39	5	15.6	2.7	10.4	11	0.06	0.02
Site 30	Broadbridge	0-7.5cm	27	7	14.4	1.3	5.8	8.1	0.04	0.2
Site 30	Broadbridge	0-18cm	26	6	13.9	1.5	5.7	7.6	0.05	0.17
Site 30	Broadbridge	23-33 cm	29	7	21	2	9.6	11.2	0.08	< 0.02
Site 31	Renwick	0-7.5cm	38	6	10.4	1.9	7.8	6.6	0.02	0.17
Site 31	Renwick	0-17cm	40	6	16.4	1.9	10.8	9.8	0.02	0.14
Site 31	Renwick	25-35cm	77	9	19.4	3.4	14.8	13.3	0.09	0.07
Site 32	Omaka	0-7.5cm	55	9	17.3	2.8	14.4	12.5	0.05	0.19
Site 32	Omaka	0-20cm	62	8	24	3	15.5	16.5	0.07	0.15
Site 32	Omaka	25-35 cm	59	7	17.9	2.9	16.1	14.7	0.11	0.04
Site 33	Awatere	0-7.5cm	54	12	20	3.8	14.5	27	0.09	0.13
Site 33	Awatere	0-20cm	52	12	24	3.3	14.3	36	0.08	0.09
Site 33	Awatere	21-31 cm	51	11	19.7	3.9	14.8	37	0.09	0.04
Site 34	Renwick	0-7.5cm	38	6	10.9	2.1	7.4	6.9	0.02	0.16
Site 34	Renwick	0-20cm	34	5	13.5	2.2	6.7	7.9	0.03	0.14
Site 34	Renwick	30-40 cm	54	8	28	3.4	10.9	17.9	0.06	0.04
Site 35	Broadbridge	0-7.5cm	59	7	15.3	3.3	21	9.8	0.08	0.13
Site 35	Broadbridge	0-20cm	63	8	15	3.2	21	10.4	0.09	0.12
Site 35	Broadbridge	23-33cm	52	7	23	3.5	25	12.2	0.14	< 0.02
Site 36	Omaka	0-7.5cm	53	8	13.4	2.8	11.6	10.6	0.04	0.14
Site 36	Omaka	0-20cm	56	7	15.2	2.7	12	11.8	0.04	0.1
Site 36	Omaka	26-36 cm	52	9	25	2.5	13.3	15.2	0.08	0.04

Table A4 Analysis Reference codes

		Chemical analysis			Physical Analysis		
Site	Soil Family	MDC Code	Depth (cm)		Lab Code	Profile	Depth (cm)
1	Wairau Mottled	WV_Soils_Site 1_Topa_0-7.5cm	0-7.5cm		HP6336	Site 1 top	0 - 7.5
1	Wairau Mottled	WV_Soils_Site 1_Topb_0-20cm	0-20cm		HP6337	Site 1 sub	30 - 37.5
1	Wairau Mottled	WV_Soils_Site 1_Sub_30-37.5cm	30-37.5cm				
2	Hillersden	WV_Soils_Site 2_Topa_0-7.5cm	0-7.5cm		HP6338	Site 2 top	0 - 7.5
2	Hillersden	WV_Soils_Site 2_Topb_0-20cm	0-20cm		HP6339	Site 2 sub	30 - 37.5
2	Hillersden	WV_Soils_Site 2_Sub_30-40cm	30-40cm				
3	Hillersden	WV_Soils_Site 3_Topa_0-7.5cm	0-7.5cm		HP6340	Site 3 top	0 - 7.5
3	Hillersden	WV_Soils_Site 3_Topb_0-20cm	0-20cm		HP6341	Site 3 sub	30 - 37.5
3	Hillersden	WV_Soils_Site 3_Sub_30-40cm	30-40cm				
4	Awatere	WV_Soils_Site 4_Topa_0-7.5cm	0-7.5cm		HP6342	Site 4 top	0 - 7.5
4	Awatere	WV_Soils_Site 4_Topb_0-20cm	0-20cm		HP6343	Site 4 sub	30 - 37.5
4	Awatere	WV_Soils_Site 4_Sub_30-40cm	30-40cm				
5	Hillersden	WV_Soils_Site 5_Topa_0-7.5cm	0-7.5cm		HP6344	Site 5 top	0 - 7.5
5	Hillersden	WV_Soils_Site 5_Topb_0-20cm	0-20cm		HP6345	Site 5 sub	23 - 30.5
5	Hillersden	WV_Soils_Site 5_Sub_23-33cm	23-33cm				
6	Broadbridge	WV_Soils_Site 6_Topa_0-7.5cm	0-7.5cm		HP6346	Site 6 top	0 - 7.5
6	Broadbridge	WV_Soils_Site 6_Topb_0-20cm	0-20cm		HP6347	Site 6 sub	22 - 29.5
6	Broadbridge	WV_Soils_Site 6_Sub_25-35cm	25-35cm				
7	Renwick	WV_Soils_Site 7_Topa_0-7.5cm	0-7.5cm		HP6348	Site 7 top	0 - 7.5
7	Renwick	WV_Soils_Site 7_Topb_0-20cm	0-20cm		HP6349	Site 7 sub	27 - 34.5
7	Renwick	WV_Soils_Site 7_Sub_30-40cm	30-40cm				
8	Hillersden	WV_Soils_Site 8_Topa_0-7.5cm	0-7.5cm		HP6350	Site 8 top	0 - 7.5
8	Hillersden	WV_Soils_Site 8_Topb_0-20cm	0-20cm		HP6351	Site 8 sub	23 - 30.5
8	Hillersden	WV_Soils_Site 8_Sub_25-35cm	25-35cm				
9	Spring Creek	WV_Soils_Site 9_Topa_0-7.5cm	0-7.5cm		HP6352	Site 9 top	0 - 7.5
9	Spring Creek	WV_Soils_Site 9_Topb_0-20cm	0-20cm		HP6353	Site 9 sub	22 - 29.5
9	Spring Creek	WV_Soils_Site 9_Sub_22-32cm	22-32cm				
10	Wairau	WV_Soils_Site 10_Topa_0-7.5cm	0-7.5cm		HP6354	Site 10 top	0 - 7.5
10	Wairau	WV_Soils_Site 10_Topb_0-20cm	0-20cm		HP6355	Site 10 sub	13 - 20.5
10	Wairau	WV_Soils_Site 10_Sub_18-28cm	18-28cm				
11	Wairau	WV_Soils_Site 11_Topa_0-7.5cm	0-7.5cm		HP6356	Site 11 top	0 - 7.5
11	Wairau	WV_Soils_Site 11_Topb_0-20cm	0-20cm		HP6357	Site 11 sub	27 - 34.5
11	Wairau	WV_Soils_Site 11_Sub_27-37cm	27-37cm				
12	Awatere	WV_Soils_Site 12_Topa_0-7.5cm	0-7.5cm		HP6358	Site 12 top	0 - 7.5
12	Awatere	WV_Soils_Site 12_Topb_0-20cm	0-20cm		HP6359	Site 12 sub	25 - 32.5
12	Awatere	WV_Soils_Site 12_Sub_25-35cm	25-35cm				
13	Hillersden	WV_Soils_Site 13_Top_0-7.5	0-7.5cm		HP6360	Site 13 top	0 - 7.5
13	Hillersden	WV_Soils_Site 13_Top_0-20	0-20cm		HP6407 Replicate 1	Site 13 sub - rep. 1	20 - 32
13	Hillersden	WV_Soils_Site 13_Sub_20-32	20-32cm				
14	Jordan	WV_Soils_Site 14_Top_0-7.5	0-7.5cm		HP6361	Site 14 top	0 - 7.5
14	Jordan	WV_Soils_Site 14_Top_0-20	0-20cm		HP6362	Site 14 sub	20 - 27.5
14	Jordan	WV_Soils_Site 14_Sub_25-35	25-35cm				

		Chemical analysis			Physical Analysis		
Site	Soil Family	MDC Code	Depth (cm)		Lab Code	Profile	Depth (cm)
15	Omaka	WV_Soils_Site 15_Top_0_7.5	0-7.5cm		HP6363	Site 15 top	0 - 7.5
15	Omaka	WV_Soils_Site 15_Top_0-20	0-20cm		HP6364	Site 15 sub	24 - 31.5
15	Omaka	WV_Soils_Site 15_Sub_24-34	24-34cm				
16	Omaka	WV_Soils_Site 16_Top_0-7.5	0-7.5cm		HP6365	Site 16 top	0 - 7.5
16	Omaka	WV_Soils_Site 16_Top_0-20	0-20cm		HP6366	Site 16 sub	18 - 25.5
16	Omaka	WV_Soils_Site 16_Sub_20-30	20-30cm				
17	Omaka	WV_Soils_Site 17_Top_0-7.5	0-7.5cm		HP6367	Site 17 top	0 - 7.5
17	Omaka	WV_Soils_Site 17_Topvine_0-7.5	0-7.5cm		HP6368	Site 17 topvine	0 - 7.5
17	Omaka	WV_Soils_Site 17_Top_0-20	0-20cm		HP6369	Site 17 sub	28 - 35.5
17	Omaka	WV_Soils_Site 17_Sub_28-38	28-38cm				
18	Wairau	WV_Soils_Site 18_Top_0-7.5	0-7.5cm		HP6370	Site 18 top	0 - 7.5
18	Wairau	WV_Soils_Site 18_Topvine_0-7.5	0-7.5cm		HP6371	Site 18 topvine	0 - 7.5
18	Wairau	WV_Soils_Site 18_Top_0-20	0-20cm		HP6372	Site 18 sub	26 - 33.5
18	Wairau	WV_Soils_Site 18_Sub_26-36	26-36cm				
19	Hillersden	WV_Soils_Site 19_Top_0-7.5	0-7.5cm		HP6373	Site 19 top	0 - 7.5
19	Hillersden	WV_Soils_Site 19_Top_0-20	0-20cm		HP6374	Site 19 sub	24 - 31.5
19	Hillersden	WV_Soils_Site 19_Sub_25-35	25-35cm				
20	Renwick	WV_Soils_Site 20_Top_0-7.5	0-7.5cm		HP6375	Site 20 top	0 - 7.5
20	Renwick	WV_Soils_Site 20_Top_0-20	0-20cm		HP6408 Replicate 1	Site 20 sub - rep. 1	25 - 36
20	Renwick	WV_Soils_Site 20_Sub_27-37	27-37cm		HP6408 Replicate 2	Site 20 sub - rep. 2	25 - 36
21	Marama	WV_Soils_Site 21_Top_0-7.5	0-7.5cm		HP6376	Site 21 top	0 - 7.5
21	Marama	WV_Soils_Site 21_Top_0-20	0-20cm		HP6377	Site 21 sub	40 - 47.5
21	Marama	WV_Soils_Site 21_Sub_40-50	40-50cm				
22	Spring Creek	WV_Soils_Site 22_Top_0-7.5	0-7.5cm		HP6378	Site 22 top	0 - 7.5
22	Spring Creek	WV_Soils_Site 22_Top_0-20	0-20cm		HP6379	Site 22 sub	22 - 29.5
22	Spring Creek	WV_Soils_Site 22_Sub_22-32	22-32cm				
23	Broadbridge	WV_Soils_Site 23_Top_0-7.5	0-7.5cm		HP6380	Site 23 top	0 - 7.5
23	Broadbridge	WV_Soils_Site 23_Top_0-20	0-20cm		HP6381	Site 23 sub	30 - 37.5
23	Broadbridge	WV_Soils_Site 23_Sub_30-40 cm	30-40 cm				
24	Marama	WV_Soils_Site 24_Top_0-7.5	0-7.5cm		HP6382	Site 24 top	0 - 7.5
24	Marama	WV_Soils_Site 24_Top_0-20	0-20cm		HP6383	Site 24 sub	22 - 29.5
24	Marama	WV_Soils_Site 24_Sub_22-32 cm	22-32 cm				
25	Broadbridge	WV_Soils_Site 25_Top_0-7.5	0-7.5cm		HP6384	Site 25 top	0 - 7.5
25	Broadbridge	WV_Soils_Site 25_Top_0-17	0-17cm		HP6385	Site 25 sub	20 - 27.5
25	Broadbridge	WV_Soils_Site 25_Sub_17-27 cm	17-27 cm				
26	Renwick	WV_Soils_Site 26_Top_0-7.5	0-7.5cm		HP6386	Site 26 top	0 - 7.5
26	Renwick	WV_Soils_Site 26_Top_0-18	0-18cm		HP6387	Site 26 sub	21 - 28.5
26	Renwick	WV_Soils_Site 26_Sub_21-31 cm	21-31 cm				
27	Renwick	WV_Soils_Site 27_Top_0-7.5	0-7.5cm		HP6388	Site 27 top	0 - 7.5
27	Renwick	WV_Soils_Site 27_Top_0-20	0-20cm		HP6389	Site 27 sub	22 - 29.5
27	Renwick	WV_Soils_Site 27_Sub_22-32 cm	22-32 cm				
28	Hillersden	WV_Soils_Site 28_Top_0-7.5	0-7.5cm		HP6390	Site 28 top	0 - 7.5
28	Hillersden	WV_Soils_Site 28_Top_0-17	0-17cm		HP6391	Site 28 sub	20 - 27.5
28	Hillersden	WV_Soils_Site 28_Sub_20-30 cm	20-30 cm				

		Chemical analysis			Physical Analysis		
Site	Soil Family	MDC Code	Depth (cm)		Lab Code	Profile	Depth (cm)
29	Renwick	WV_Soils_Site 29_Top_0-7.5	0-7.5cm		HP6392	Site 29 top	0 - 7.5
29	Renwick	WV_Soils_Site 29_Top_0-16	0-16cm		HP6393	Site 29 sub	22 - 29.5
29	Renwick	WV_Soils_Site 29_Sub_22-32 cm	22-32 cm				
30	Broadbridge	WV_Soils_Site 30_Top_0-7.5	0-7.5cm		HP6394	Site 30 top	0 - 7.5
30	Broadbridge	WV_Soils_Site 30_Top_0-18	0-18cm		HP6395	Site 30 sub	23 - 30.5
30	Broadbridge	WV_Soils_Site 30_Sub_23-33 cm	23-33 cm				
31	Renwick	WV_Soils_Site 31_Top_0-7.5	0-7.5cm		HP6396	Site 31 top	0 - 7.5
31	Renwick	WV_Soils_Site 31_Top_0-17	0-17cm		HP6409 Replicate 1	Site 31 sub - rep. 1	25 - 35
31	Renwick	WV_Soils_Site 31_Sub_25-35cm	25-35cm		HP6409 Replicate 2	Site 31 sub - rep. 2	25 - 35
32	Omaka	WV_Soils_Site 32_Top_0-7.5	0-7.5cm		HP6397	Site 32 top	0 - 7.5
32	Omaka	WV_Soils_Site 32_Top_0-20	0-20cm		HP6398	Site 32 sub	25 - 32.5
32	Omaka	WV_Soils_Site 32_Sub_25-35 cm	25-35 cm				
33	Awatere	WV_Soils_Site 33_Top_0-7.5	0-7.5cm		HP6399	Site 33 top	0 - 7.5
33	Awatere	WV_Soils_Site 33_Top_0-20	0-20cm		HP6400	Site 33 sub	21 - 28.5
33	Awatere	WV_Soils_Site 33_Sub_21-31 cm	21-31 cm				
34	Renwick	WV_Soils_Site 34_Top_0-7.5	0-7.5cm		HP6401	Site 34 top	0 - 7.5
34	Renwick	WV_Soils_Site 34_Top_0-20	0-20cm		HP6402	Site 34 sub	32 - 39.5
34	Renwick	WV_Soils_Site 34_Sub_30-40 cm	30-40 cm				
35	Broadbridge	WV_Soils_Site 35_Top_0-7.5	0-7.5cm		HP6403	Site 35 top	0 - 7.5
35	Broadbridge	WV_Soils_Site 35_Top_0-20	0-20cm		HP6404	Site 35 sub	23 - 30.5
35	Broadbridge	WV_Soils_Site 35_Sub_23-33cm	23-33cm				
36	Omaka	WV_Soils_Site 36_Top_0-7.5	0-7.5cm		HP6405	Site 36 top	0 - 7.5
36	Omaka	WV_Soils_Site 36_Top_0-20	0-20cm		HP6406	Site 36 sub	26 - 33.5
36	Omaka	WV_Soils_Site 36_Sub_26-36 cm	26-36 cm				

Appendix B – Soil Profile Descriptions

Sample Name: Site WV1
Soil Name: Wairau family (mottled)
GPS: 41 32.736 S 173 34.736 E
Land use: grazing
Elevation: 134m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: moderately well drained

Horizon	Depth	Description
A	0-21cm	very dark grayish brown (10YR 3/2) fine sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable many fine and few coarse roots
AB	21-30cm	very dark grayish brown and dark yellowish brown (10YR 3/2 + 10YR 4/4) fine sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; common fine and few coarse roots
BC	30-42cm	olive brown (2.5Y 4/4) fine sandy loam; weakly developed coarse blocky structure; weak soil strength; compact; friable; few fine roots
C(g)	42-64cm	olive brown (2.5Y 4/4) fine sandy loam; 10% yellowish brown (10YR 5/6) and 30% dark grayish brown (2.5Y 6/2) fine mottles; apedal; compact; friable; few fine roots
C	64-70cm+	olive brown (2.5Y 4/4) loamy sand; apedal; 60% coarse stones

Sample Name: Site WV2
Soil Name: Hillersden family
GPS: 41 32.923 S 173 34.406 E
Land use: grazing
Elevation: 139m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20 cm	dark brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 10% fine and medium stones; abundant fine roots
AB	20-28cm	dark brown and dark yellowish brown (10YR 3/3+ 10YR 4/6) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; common fine roots
Bw	28-60cm	dark yellowish brown (10YR 4/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; few fine roots
BC	60-70cm	dark yellowish brown to olive brown (10YR 4/4-2.5Y 4/4) coarse sand; apedal; very weak soil strength; loose
C	70-75cm+	olive brown (2.5Y 4/4) coarse sand; apedal; 70% medium to coarse stones

Sample Name: Site WV3
Soil Name: Hillersden family
GPS: 41 32,711 S 173 35.992 E
Land use: grazing
Elevation: 137m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-23cm	dark brown (10YR 3/3) heavy silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
AB	23-27cm	dark brown and dark yellowish brown (10YR 3/3 + 10YR 5/6) heavy silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; common fine roots
Bw1	27-50cm	dark yellowish brown (10YR 5/6) clay loam; moderately developed fine polyhedral structure; slightly firm soil strength; compact; friable few fine roots
Bw2	50-70cm	light olive brown (2.5Y 5/4) clay loam; 15% yellowish brown and 45% light brownish grey (10YR 5/4 +10YR 6/2) fine distinct mottles; moderately developed coarse blocky structure; firm soil strength; compact; brittle fracture
BC(g)	70-85cm	light olive brown to pale brown (2.5Y 5/4 + 10YR 6/3) clay loam; 25% strong brown (7.5YR 5/6) medium mottles; weakly developed coarse blocky structure; firm soil strength; dense; brittle fracture; 5% fine and medium stones

Sample Name: Site WV4
Soil Name: Awatere family
GPS: 41 32.139 S 173 35.648 E
Land use: grazing
Elevation: 126m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: floodplain system
Soil drainage: well drained

Horizon	Depth	Description
A	0-18cm	very dark greyish brown (10YR 3/2) silt loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; many fine roots
AC	18-30cm	very dark greyish brown to dark grayish brown (10YR 3/3-10YR 4/2) silt loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; few fine roots
C1	30-50cm	dark grayish brown (10YR 4/2) silt loam; apedal; very weak soil strength; compact; very friable; few fine roots
C2	50-60cm+	dark grayish brown (10YR 4/2) sandy loam; apedal; 60% medium to very coarse stones

Sample Name: Site WV5
Soil Name: Hillersden family
GPS: 41 34.851 S 173 29.959 E
Land use: grazing
Elevation: 186m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: moderately well drained

Horizon	Depth	Description
A	0-20cm	dark brown to dark yellowish brown (10YR 3/3-10YR 3/4) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 2% fine stones; many fine roots
AB	20-23cm	dark brown and dark yellowish brown (10YR 3/3+10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; very friable; common fine roots
Bw	23-45cm	dark yellowish brown (10YR 5/6) heavy silt loam; moderately developed coarse blocky structure; slightly firm soil strength; compact; friable; 2% medium stones; few fine roots
B(g)	45-65cm	dark yellowish brown (10YR 5/8) sandy silt loam; 15% yellowish red (5YR 5/6) and 25% olive grey (5Y 5/2) medium mottles; weakly developed coarse blocky structure; slightly firm soil strength; compact; brittle fracture; few fine roots
BC(g)	65-69cm+	olive brown (2.5Y 5/4) sandy loam; 10% yellowish red (5YR 5/6) and 10% light brownish grey (2.5Y 6/2) medium mottles; apedal; dense; 70% medium and coarse stones

Sample Name: Site WV6
Soil Name: Broadbridge family
GPS: 41 35.233 S 173 30.085 E
Land use: grazing
Elevation: 181m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: imperfectly drained

Horizon	Depth	Description
A	0-15cm	very dark grayish brown (10YR 3/2) clay; 10% yellowish red (5YR 5/8) fine mottles along root channels; moderately developed fine polyhedral structure; slightly firm soil strength; compact; friable; abundant fine roots
Bg1	15-35cm	40% yellowish red (5YR 5/8) and 40% olive grey (5Y 5/2) mottled clay; strongly developed coarse blocky structure; firm soil strength; dense; semi-deformable fracture; common fine roots
Bg2	35-55cm	30% strong brown (7.5YR 5/8) and 70% grey (5Y 5/1) clay; strongly developed coarse blocky structure; very firm soil strength; dense; semi-deformable fracture; few fine roots
BCg1	55-62cm	45% strong brown (7.5YR 4/6) and 55% light olive grey to light brownish grey (5Y 6/2-2.5Y 6/2) clay loam; moderately developed coarse blocky structure; very firm soil strength; very dense; brittle fracture;
BCg2	62-69cm+	45% strong brown (7.5YR 4/6) and 55% light olive grey to light brownish grey (5Y 6/2-2.5Y 6/2) sandy clay loam; apedal; 45% medium to coarse stones

Sample Name: Site WV7
Soil Name: Renwick family
GPS: 41 35.557 S 173 28.762 E
Land use: lucerne
Elevation: 199m
Soil Material: greywacke alluvium
Slope: 3º
Landscape: midslope colluvial fan
Soil drainage: well drained

Horizon	Depth	Description
A	0-22cm	very dark grayish brown (10YR 3/2) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 15% fine stones; abundant fine and few coarse roots
AB	22-27cm	very dark grayish brown (10YR 3/2) and yellowish brown (10YR 5/6) sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 5% fine stones; common fine and few coarse roots
Bw	27-55cm	yellowish brown (10YR 5/6) silt loam; weakly developed coarse blocky structure; slightly firm soil strength; compact; brittle fracture; 2% fine stones; few fine and few coarse roots
BC	55-67cm	light olive brown (2.5Y 5/4) sandy silt loam; apedal;70% fine to medium stones; dense

Sample Name: Site WV8
Soil Name: Hillersden family
GPS: 41 35.557 S 173 28.762 E
Land use: grazing
Elevation: 195m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	dark yellowish brown (10YR3/4) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
AB	20-23cm	yellowish brown and dark yellowish brown (10YR 5/6 + 10YR3/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; common fine roots
Bw	23-45cm	yellowish brown ((10YR 5/4) silty clay loam; moderately developed coarse blocky structure; slightly firm soil strength; brittle fracture; few fine roots
BC	45-55+cm	yellowish brown (10YR 5/8) sandy clay loam; apedal; dense; 75% fine to coarse stones

Sample Name: Site WV9
Soil Name: Spring Creek family
GPS: 41 34.472 S 173 29.651 E
Land use: grazing
Elevation: 173m
Soil Material: greywacke alluvium
Slope: 2º
Landscape: low terrace system
Soil drainage: poorly drained

Horizon	Depth	Description
A	0-22cm	very dark grayish brown (10YR 3/2) sandy silt loam; 5% red (2.5YR 4/8) fine mottles along root channels; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 2% fine stones; abundant fine roots
Bg	22-35cm	60% light grey (2.5Y 6/2) and 40% strong brown (7.5YR5/6) mottled (medium) silt loam; moderately developed coarse blocky structure; slightly firm soil strength; compact; brittle fracture; common roots
BCg	35-45cm	60% light brownish grey (10YR 6/2) and 40% yellowish red (5YR 4/8) sandy silt loam; moderately developed coarse blocky structure; slightly firm soil strength; compact; brittle fracture; 5% medium to coarse stones; few fine roots
Cg	45-55cm	grey (10YR 5/1) sandy gravel; apedal; 40% medium to coarse stones; loose; few fine roots

Sample Name: Site WV10
Soil Name: Wairau family
GPS: 41 34.827 S 173 29.891 E
Land use: grazing
Elevation: 171m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-16cm	dark brown (10YR 3/3) silt loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; 5% fine stones; many fine roots
BC1	16-25cm	dark yellowish brown (10YR 4/4) silt loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; 10% medium to coarse stones; abundant fine roots
BC2	25- 47cm	dark yellowish brown (10YR 4/4) sandy loam; weakly developed fine polyhedral structure; compact; friable; 40% medium to coarse stones; common fine roots
C	47-65cm+	light olive brown (2.5Y 5/4) coarse sand; apedal; loose; 65% medium to very coarse stones; few fine roots

Sample Name: Site WV11
Soil Name: Wairau family
GPS: 41 34.981 S 173 28.413 E
Land use: grazing
Elevation: 183m
Soil Material: greywacke alluvium
Slope: 2º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	dark brown (10YR 3/3) silt loam; weakly developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
AB	20-27cm	dark brown (10YR 3/3) and dark yellowish brown (10YR 4/4) sandy loam; weakly developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
BC	27-37cm	dark yellowish brown to light olive brown (10YR 4/4-2.5Y 5/4) sandy loam; weakly developed fine polyhedral and coarse blocky structure; weak soil strength; compact; friable; 5% medium stones; common fine roots
C1	37-45cm	olive grey (2.5Y 4/2) sand; apedal; very weak soil strength; compact; very friable; 5% medium stones
C2	45-55cm	olive (5Y 4/4) coarse sand; apedal; very weak soil strength
C3	55-65cm+	yellowish red (5YR 4/6) coarse sand; apedal; firm; compact; brittle failure; 60% medium to coarse stones

Sample Name: Site WV12
Soil Name: Awatere family
GPS: 41 34.760 S 173 28.261 E
Land use: grazing
Elevation: 188m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	very dark grayish brown (10YR 3/2) sandy loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; abundant fine roots
AB	20-25cm	very dark grayish brown and light olive brown (10YR 3/2 + 2.5Y 5/4) sandy loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; common fine roots
BC	25-50cm	light olive brown to brown (2.5Y 5/4-10YR 4/3) fine sandy loam; weakly developed fine polyhedral and medium blocky structure; weak soil strength; compact; friable; few fine roots
C1	50-65cm	olive brown (2.5Y 4/4) sandy loam; apedal; weak soil strength; compact; brittle failure; few fine roots
C2	65cm+	olive brown sandy loam; compact; 60% coarse to very coarse stones

Sample Name: Site WV13
Soil Name: Hillersden family
GPS: 41 33,256 S 173 34,563 E
Land use: grazing
Elevation: 143m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	yellowish brown (10YR 5/6) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 5% medium to coarse stones; abundant roots
Bw1	20-25cm	strong brown (7.5YR 5/6) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 5% medium to coarse stones; abundant roots
Bw2	25-45cm	strong brown (7.5YR 5/6) sandy loam; moderately developed fine polyhedral and medium blocky structure; compact; friable; 40% medium to coarse stones; common fine roots
BC	45-70cm	dark yellowish brown (10YR 4/4) coarse sand; apedal; compact; loose; 40% fine to coarse stones; few fine roots

Sample Name: Site WV14
Soil Name: Jordan family
GPS: 41 33,379 S 173 34,710 E
Land use: grazing
Elevation: 176m
Soil Material: loess over gravel
Slope: 3º
Landscape: dissected high terrace system
Soil drainage: moderately well drained

Horizon	Depth	Description
A	0-20cm	dark yellowish brown (10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
AB	20-23cm	dark yellowish brown and brownish yellow (10YR 4/4 + 10YR 6/8) silt loam; moderately developed fine polyhedral and coarse blocky structure; weak soil strength; compact; friable; occasional medium stones; many fine roots
Bw	23-38cm	25% yellowish brown (10YR 5/8) and 60% light yellowish brown (2.5Y 6/4) mottled heavy silt loam; moderately developed coarse to very coarse blocky and prismatic structure; very firm soil strength; dense; brittle failure; occasional medium stones; few roots
Bw(g)	38-55cm	35% strong brown (7.5YR 5/8) and 50% very pale brown and pale yellow (10YR 7/3+2.5Y 7/4) mottled heavy silt loam; moderately developed coarse to very coarse blocky and prismatic structure; very firm soil strength; dense; brittle failure; few roots
Bx	55-65cm+	50% strong brown (7.5YR 5/8) heavy silt loam with very pale brown (10YR 7/4) and grayish brown (10YR 5/2) coarse platy and veined mottles at the horizon surface; moderately developed very coarse prismatic structure; hard soil strength; very dense; brittle failure

Sample Name: Site WV15
Soil Name: Omaka family
GPS: 41 38.291 S 173 18,035 E
Land use: grazing
Elevation: 288m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	dark yellowish brown (10YR 3/4) fine sandy loam; moderately developed fine and medium polyhedral structure; weak soil strength; compact; very friable; abundant fine roots
AB	20-24cm	dark yellowish brown and yellowish brown (10YR3/4 +10YR 5/6) fine sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; common fine roots
Bw	24-35cm	yellowish brown (10YR 5/6) sandy loam; weakly developed fine polyhedral and coarse blocky structure; slightly firm soil strength; compact; friable; common fine roots
BC	35-45cm	yellowish brown to light olive brown (10YR 5/6-2.5Y 5/4) loamy sand; weakly developed medium blocky structure; very weak soil strength; compact; friable; few fine roots

Sample Name: Site WV16
Soil Name: Omaka family
GPS: 41 38.484 S 173 18,067 E
Land use: grazing
Elevation: 291m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-18cm	dark yellowish brown (10YR3/4) silt loam; strongly developed fine and medium polyhedral structure; weak soil strength; compact; very friable; 2% fine to medium stones; abundant fine roots
AB	18-22cm	dark yellowish brown and yellowish brown (10YR3/4 + 10YR 5/6) silt loam; moderately developed fine and medium polyhedral structure; weak soil strength; compact; friable; 2% fine to medium stones; abundant fine roots
Bw	22-35cm	yellowish brown (10YR 5/6) silt loam; weakly developed fine polyhedral and coarse blocky structure; weak soil strength; compact; very friable; 2% medium stones; many fine roots
BC	35-50cm	light olive brown (2.5Y 5/6) silt loam; weakly developed coarse blocky structure; slightly firm soil strength; compact; brittle failure; few fine roots
C	50-70cm+	olive brown (2.5Y 4/4) fine sandy loam; apedal; slightly firm soil strength; compact; brittle failure

Sample Name: Site WV17
Soil Name: Omaka family
GPS: 41 35.532 S 173 26.239 E
Land use: viticulture
Elevation: 207m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	very dark grayish brown (10YR 3/2) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
AB	20-25cm	very dark grayish brown and dark yellowish brown (10YR 3/2 + 10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
Bw	25-47cm	dark yellowish brown (10YR 4/4) silt loam; moderately developed fine polyhedral and coarse blocky structure; weak soil strength; compact; very friable; common fine roots
BC	47-65cm	light olive brown (2.5Y 5/6) sandy silt loam; few yellowish red (5YR 5/8) fine mottles; weakly developed coarse blocky structure; weak soil strength; compact friable 5% fine to medium stones; few fine roots
C	65-70cm+	light olive brown (2.5Y 5/4) sandy loam; apedal; slightly firm; compact; 20% fine to medium stones

Sample Name: Site WV18
Soil Name: Wairau family
GPS: 41 35.278 S 173 26.270 E
Land use: viticulture
Elevation: 204m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-22cm	dark brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; abundant fine roots
AB	22-26cm	dark brown and dark yellowish brown (10YR 3/3 +10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; very friable; common fine roots
B(w)	26-40cm	dark yellowish brown (10YR 4/4) fine sandy loam; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; common fine roots
BC	40-55cm	light olive brown to dark yellowish brown (2.5Y 4/6-10YR 4/4) fine sand; apedal very weak soil strength; compact; very friable; few fine roots
C	55-80cm+	olive brown (2.5Y 4/4) sand; apedal; loose; few fine roots

Sample Name: Site WV19
Soil Name: Hillersden family
GPS: 41 36.190 S 173 26.247 E
Land use: grazing
Elevation: 224m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: high terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	dark yellowish brown (10YR 3/4) sandy silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 25% fine to medium stones; abundant fine roots
AB	20-24cm	dark yellowish brown and yellowish brown (10YR3/4 + 10YR 5/6) sandy loam; moderately medium polyhedral structure; weak soil strength; compact; very friable; 15% fine to medium stones; many fine roots
Bw1	24-38cm	dark yellowish brown (10YR 4/6) sandy loam; strongly developed fine polyhedral structure; very weak soil strength; compact; very friable; <5% fine and medium stones; many fine roots
Bw2	38-50cm	dark yellowish brown (10YR 4/6) sand; apedal; dense; 65% fine to coarse stones; very few fine roots
BC	50-65cm+	olive brown to dark yellowish brown (2.5Y 4/4-10YR 4/4) coarse sand; apedal; loose; 70% fine to coarse stones

Sample Name: Site WV20
Soil Name: Renwick family
GPS: 41 36.042 S 173 26.678 E
Land use: grazing
Elevation: 226m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: colluvial fan
Soil drainage: well drained

Horizon	Depth	Description
A	0-21cm	dark brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; very weak soil strength; compact; very friable; 25% fine to medium stones; abundant fine roots
AB	21-26cm	dark brown and dark yellowish brown (10YR 3/3 +10YR 4/6) sandy silt loam; compact; very friable; 35% fine to medium stones; many fine roots
Bw	26-50cm	dark yellowish brown (10YR 4/6) sandy silt loam; weakly developed fine polyhedral structure; compact; friable; 65% fine to medium stones; many fine roots
BC	50-65cm+	dark yellowish brown (10YR 4/6) sand; apedal; compact; 70% fine to coarse stones; few fine roots

Sample Name: Site WV21
Soil Name: Marama family
GPS: 41 35.819 S 173 26.379 E
Land use: grazing
Elevation: 213m
Soil Material: greywacke stream alluvium
Slope: 0º
Landscape: stream floodplain
Soil drainage: well drained

Horizon	Depth	Description
A	0-17cm	dark brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; very weak soil strength; compact; very friable; 5% fine stones; many fine roots
b A	17-33cm	very dark grayish brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 5% fine to coarse stones at the horizon base; common fine roots
b Bw	33-57cm	light olive brown to dark yellowish brown (2.5Y 5/6-10YR 4/4) heavy silt loam; moderately developed coarse blocky structure; weak soil strength; compact; very friable; 10% medium to coarse stones; few fine roots
BC	57-75cm+	light olive brown (2.5Y 5/6) clay loam; apedal; dense; 20% medium to coarse stones

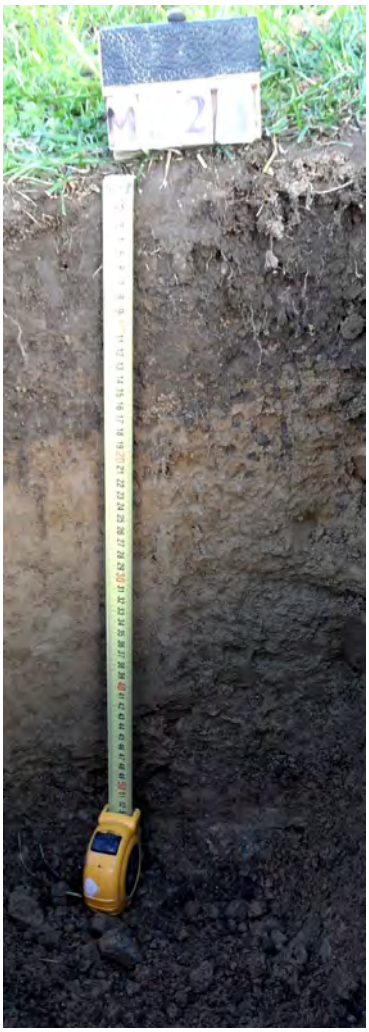
Sample Name: Site WV22
Soil Name: Spring Creek family
GPS: 41 35.841 S 173 26.208 E
Land use: grazing
Elevation: 212m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace back slope
Soil drainage: imperfectly drained

Horizon	Depth	Description
A(g)	0-20cm	dark grayish brown (10YR 4/2) sandy silt loam; 5% fine yellowish red (5YR 4/8) mottles along root channels; moderately developed fine polyhedral structure; very weak soil strength; compact; very friable; 5% medium stones; abundant fine roots
B(g)	20-40cm	30% yellowish red (5YR 5/8) and 45% olive (5Y 5/3) mottled silt loam; moderately developed fine polyhedral and coarse blocky structure; weak soil strength; compact; friable; 5% medium stones; many fine roots
BC(g)	40-55cm	light brownish grey (2.5Y 6/2) silt loam; 10% Strong brown (7.5YR 5/8) medium mottles; Weakly developed coarse blocky structure; Slightly firm soil strength; compact; brittle failure; 5% medium to coarse stones; few fine roots
C(g)	55-60cm	olive brown (2.5Y 4/4) coarse sand; 15% strong brown (7.5YR 5/8) medium mottles; apedal; compact; 70% medium to coarse stones

Sample Name: Site WV23
Soil Name: Broadbridge family
GPS: 41 39.548 S 173 15.964 E
Land use: dairying
Elevation: 307m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: high terrace back slope
Soil drainage: imperfectly drained

Horizon	Depth	Description
A	0-20cm	very dark grayish brown (10YR 3/2) clay loam; moderately developed fine and medium polyhedral structure; 5% yellowish red (5YR 5/8) fine mottles along root channels; weak soil strength; compact; friable; many fine roots
AB	26-30cm	brown (10YR 5/3) and strong brown (7.5YR 5/8) mottled clay loam; moderately developed fine polyhedral and coarse blocky structure; weak soil strength; compact; friable; common fine roots
B(g)1	30-36cm	50% strong brown (7.5YR 5/8) and 60% pale brown (10YR 6/3) and brown (10YR 5/3) mottled clay loam, light grey (10YR 6/1) on ped faces; strongly developed coarse blocky structure; slightly firm soil strength; dense; brittle failure; few fine roots
B(g)2	36-46cm	olive yellow (2.5Y 6/6) clay; 40% strong brown (7.5YR 5/6) and 40% brownish yellow (10YR 6/6) medium mottles; strongly developed coarse blocky structure; firm soil strength; dense; brittle failure; few fine roots
BC(g)	46-85cm	dark yellowish brown (10YR 5/6) clay loam; 20% strong brown (7.5YR 5/8) and 30% light brownish grey (2.5Y 6/2) coarse mottles in veins; moderately developed very coarse prismatic structure; very firm soil strength; dense; brittle failure

Sample Name: Site WV24
Soil Name: Marama family
GPS: 41 39.307 S 173 16.048 E
Land use: dairying
Elevation: 308m
Soil Material: greywacke stream alluvium
Slope: 0º
Landscape: stream terrace
Soil drainage: well drained



Horizon	Depth	Description
A	0-18cm	very dark grayish brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 2% medium stones; abundant fine roots
AB	18-22cm	very dark grayish brown and yellowish brown (10YR 3/3 + 10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
Bw	22-35cm	brown to dark yellowish brown (10YR 4/6-5/6) silt loam; weakly developed coarse blocky and fine polyhedral structure; weak soil strength; compact; friable; 2% medium stones; common fine roots
BC1	35-50cm	light olive brown (2.5Y 5/6) heavy silt loam; weakly developed medium and coarse blocky structure; weak soil strength; compact; friable; few fine roots
C2	50-65cm	light olive brown (2.5Y 5/6) sandy silt loam; apedal; dense; 60% medium to coarse stones

Sample Name: Site WV25
Soil Name: Broadbridge family
GPS: 41 39.364 S 173 16.739 E
Land use: dairying
Elevation: 306m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: fan toe slope
Soil drainage: poor

Horizon	Depth	Description
A	0-17cm	very dark grey (10YR 3/1) silt loam; moderately developed fine and medium polyhedral structure; weak soil strength; compact; friable; 2% medium stones; many fine roots
AB(g)	17-20cm	very dark grey (10YR 3/1) and strong brown and grayish brown (2.5Y 5/2 + 7.5YR 5/6) mottled heavy silt loam; moderately developed fine polyhedral and coarse blocky structure; slightly firm; compact; semi-deformable failure; 2% medium stones; common fine roots
Bg	20-35cm	50% grayish brown (2.5Y 5/2) and 50% strong brown (7.5YR 5/6) mottled heavy silt loam; strongly developed coarse blocky structure; slightly firm soil strength; compact; semi-deformable failure; 5% medium stones; few fine roots
BCr	35-60cm+	light brownish grey (10YR 6/2) silt loam; 10% strong brown (7.5YR 5/6) fine mottles; apedal, very wet; 45% medium to coarse stones

Sample Name: Site WV26
Soil Name: Renwick family
GPS: 41 39.495 S 173 16.682 E
Land use: grazing
Elevation: 308m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: fan mid slope
Soil drainage: well drained

Horizon	Depth	Description
A	0-18cm	brown to dark brown (10YR 4/3) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 5% fine to medium stones; many fine roots
AB	18-21cm	brown to dark brown (10YR 4/3) and brownish yellow (10YR 6/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; 5% fine and medium stones; many fine roots
Bw	21-37cm	brownish yellow (10YR 6/6) heavy silt loam; moderately developed fine polyhedral and coarse blocky structure; slightly firm soil strength; compact; friable; 10% fine stones; common fine roots
BC1	37-44cm	brownish yellow to light olive brown (10YR 6/6-2.5Y 5/6) heavy silt loam; weakly developed coarse blocky structure; slightly firm soil strength; brittle failure; 5% fine to medium stones; few fine roots
BC2	44-65cm	light olive brown (10YR 6/6) heavy silt loam; apedal; compact; 40% fine to coarse stones

Sample Name: Site WV27
Soil Name: Renwick family
GPS: 41 39.031 S 173 14.660 E
Land use: grazing
Elevation: 308m
Soil Material: greywacke colluvium
Slope: 0º
Landscape: fan mid slope
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	dark brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; friable; 5% fine stones; common fine roots
AB	20-22cm	dark brown and yellowish brown (10YR 3/3+10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 5% fine to medium stones; common fine roots
Bw1	22-43cm	yellowish brown (10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; very friable; 10% fine to medium stones; few fine roots
Bw2	43-52cm+	yellowish brown (10YR 5/8) sandy silt loam; weakly developed fine polyhedral structure; compact; 55% fine to medium stones; few fine roots
BC	52-60cm+	light olive brown (2.5Y 5/6) coarse sand; apedal; compact; 70% fine to coarse stones

Sample Name: Site WV28
Soil Name: Hillersden family
GPS: 41 39.117 S 173 15.877 E
Land use: dairying
Elevation: 317m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: intermediate terrace system?
Soil drainage: well drained

Horizon	Depth	Description
A	0-16cm	dark yellowish brown (10YR 3/4) silt loam; strongly developed fine polyhedral structure; very weak soil strength; compact; very friable; 5% fine to very coarse stones; abundant fine roots
AB	16-19cm	dark yellowish brown and yellowish brown (10YR3/4+5/6) silt loam; strongly developed fine polyhedral structure; very weak soil strength; compact; very friable; 5% fine to coarse stones; many fine roots
Bw1	19-32cm	yellowish brown (10YR 5/6) silt loam; moderately developed fine and medium polyhedral structure; weak soil strength; compact; friable; 5% fine to coarse stones; many fine roots
Bw2	32-52cm	yellowish brown (10YR 5/6) sandy silt loam; weakly developed fine polyhedral and medium blocky structure; compact; friable; 30% medium to coarse stones; common fine roots
BC	52-65cm+	light olive brown (2.5Y 5/6) coarse sand; apedal; compact; 65% medium to very coarse stones

Sample Name: Site WV29
Soil Name: Renwick family
GPS: 41 39.566 S 173 14.342 E
Land use: grazing
Elevation: 342m
Soil Material: greywacke colluvium
Slope: 1º
Landscape: midslope fan surface
Soil drainage: well drained

Horizon	Depth	Description
A	0-17cm	very dark grayish brown (10YR 3/3) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 10% fine stones; abundant fine roots
AB	17-21cm	very dark grayish brown and yellowish brown (10YR 3/3+ 10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
Bw	21-52cm	dark yellowish brown (10YR 5/6) heavy silt loam; moderately developed medium blocky and fine polyhedral structure; very weak soil strength; compact; very friable; 10% fine to medium stones; common fine roots
BC	52-65cm	light olive brown to yellowish brown (2.5Y 5/6-10YR 5/6) silt loam; weakly developed coarse blocky structure; very weak soil strength; compact; friable; 15% fine to medium stones; common roots
C	65-80cm+	light olive brown (2.5Y 5/6) sandy silt loam; apedal; compact; 45% fine to medium stones

Sample Name: Site WV30
Soil Name: Broadbridge family
GPS: 41 39.804 S 173 14.618 E
Land use: grazing
Elevation: 344m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: toeslope fan surface
Soil drainage: moderately well drained

Horizon	Depth	Description
A	0-19cm	dark brown (10YR 3/3) silt loam; moderately developed fine and medium polyhedral structure; weak soil strength; compact; friable; abundant fine roots
AB	19-23cm	light yellowish brown and dark brown (10YR 6/4, 10YR 5/3) heavy silt loam; moderately developed medium polyhedral structure; weak soil strength; compact; friable; many fine roots
Bw	23-33cm	light yellowish brown (10YR 6/4) heavy silt loam; 5% yellowish red (5YR 4/6) fine mottles; moderately developed fine polyhedral structure; weak soil strength; compact; friable; many fine roots
B(g)	33-50cm	light yellowish brown to yellowish brown (10YR 6/4-5/4) heavy silt loam; 25% strong brown (7.5YR 5/6) medium mottles; moderately developed coarse blocky structure; weak soil strength; compact; friable; few fine roots
BC(g)	50-85cm	40% strong brown (7.5YR 5/8) and 60% light yellowish brown (2.5Y 6/4) coarsely mottled silt loam; moderately developed coarse and very coarse blocky and prismatic structure; slightly firm soil strength; compact; brittle failure

Sample Name: Site WV31
Soil Name: Renwick family
GPS: 41 37.700 S 173 22.865 E
Land use: grazing
Elevation: 273m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: upper midslope fan surface
Soil drainage: well drained

Horizon	Depth	Description
A	0-17cm	dark yellowish brown (10YR3/4) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 20% fine to medium stones; abundant fine roots
AB	17-24cm	dark yellowish brown (10YR3/4 + 4/6) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; 20% fine to coarse stones; 20% fine to coarse stones; abundant fine roots
Bw	24-46cm	dark yellowish brown (10YR 4/6) sandy loam; strongly developed fine polyhedral structure; compact; friable; 35% fine to coarse stones; abundant fine roots
BC	46-65cm+	dark yellowish brown to light olive brown (10YR 4/6-2.5Y 5/6) sandy loam; apedal; loose; 65% fine to very coarse stones

Sample Name: Site WV32
Soil Name: Omaka family
GPS: 41 37.107 S 173 22.542 E
Land use: grazing
Elevation: 248m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-20cm	very dark grayish brown (10YR 3/3) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; abundant fine roots
AB	20-25cm	very dark grayish brown and dark yellowish brown (10YR 3/3 + 10YR 4/4) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 2% medium stones abundant fine roots
Bw	25-45cm	dark yellowish brown (10YR 4/4) silt loam; weakly developed coarse blocky and fine polyhedral structure; weak soil strength; compact; friable; 5% medium to coarse stones; few fine roots
BC	45-65cm	light olive brown (2.5Y 5/6) sandy loam; apedal; very weak soil strength; compact; friable 25% medium to very coarse stones; few fine roots

Sample Name: Site WV33
Soil Name: Awatere family
GPS: 41 32.119 S 173 20.519 E
Land use: viticulture
Elevation: 257m
Soil Material: greywacke alluvium
Slope: 3º
Landscape: low terrace/floodplain system
Soil drainage: well drained

Horizon	Depth	Description
A	0-17cm	dark brown (10YR 3/3) loamy sand; weakly developed fine polyhedral structure; very weak soil strength; compact; very friable; abundant fine and few coarse roots
AC	17-21cm	dark brown (10YR 3/3) and olive (5Y 4/3) loamy sand; weakly developed fine polyhedral structure; very weak soil strength; very friable few fine and few coarse roots
C1	21-80cm	olive (5Y 4/4) sand; apedal; loose; few fine and few coarse roots
C2	80-90cm+	olive (5Y 4/4) sand; apedal; loose; 20% very coarse stones; few coarse roots

Sample Name: Site WV34
Soil Name: Renwick family
GPS: 41 37.371 S 173 22.983 E
Land use: grazing
Elevation: 259m
Soil Material: greywacke colluvium
Slope: 2º
Landscape: fan system
Soil drainage: well drained

Horizon	Depth	Description
A	0-22cm	dark brown (10YR 3/2) sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 20% fine to medium stones; common fine and coarse roots
AB	22-27cm	dark brown and yellowish brown (10YR 3/2+10YR 5/2) sandy loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; 20% fine to medium stones; common fine and few coarse roots
Bw	27-50cm	yellowish brown (10YR 5/6) sandy loam; moderately developed fine polyhedral structure; slightly firm soil strength; compact; 15% fine stones; few fine and few coarse roots
BC	50-65cm	light olive brown (2.5Y 5/6) sand; weakly developed coarse blocky structure; compact; friable; 35% medium to coarse stones; few fine roots
C	65-77cm	olive brown (2.5Y 5/4) sand; apedal; loose; 65% medium to coarse stones

Sample Name: Site WV35
Soil Name: Broadbridge family
GPS: 41 37.865 S 173 21.153 E
Land use: grazing
Elevation: 264m
Soil Material: greywacke colluvium
Slope: 0º
Landscape: toe slope fan system
Soil drainage: imperfectly drained

Horizon	Depth	Description
A	0-20cm	dark brown (10YR3/4) heavy silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
AB	20-23cm	dark brown and yellowish brown (10YR3/4 +10YR 5/8) clay loam; moderately developed fine polyhedral structure; weak soil strength; compact; friable; abundant fine roots
Bw	23-35cm	yellowish brown (10YR 5/8) clay loam; moderately developed fine polyhedral structure; weak soil strength; compact; very friable; 5% dark brown (7.5YR 3/2) soft concretions; abundant fine roots
Bg1	35-50cm	light brownish grey (10YR 6/2) clay loam; 20% strong brown (7.5YR 5/6) medium mottles; moderately developed fine and coarse polyhedral and blocky structure; slightly firm soil strength; compact; brittle failure; few fine roots
Bg2	50-65cm	light grayish brown to grayish brown (10YR 6/2-5/2) clay loam; 10% strong brown (7.5YR 5/6) medium mottles; moderately developed coarse blocky structure; slightly firm soil strength; brittle failure; few fine roots
BCg	65-75cm	light grayish brown (10YR 6/2) clay loam; 30% yellowish brown to strong brown (10YR 5/4-7.5YR 5/6) medium mottles; apedal; very firm soil strength; dense; brittle failure; 15% medium to coarse stones

Sample Name: Site WV36
Soil Name: Omaka family
GPS: 41 37.675 S 173 20.846 E
Land use: grazing
Elevation: 260m
Soil Material: greywacke alluvium
Slope: 0º
Landscape: low terrace system
Soil drainage: well drained

Horizon	Depth	Description
A	0-22cm	dark yellowish brown (10YR3/4) silt loam; strongly developed fine polyhedral structure; weak soil strength; compact; very friable; abundant fine roots
AB	22-26cm	dark yellowish brown and yellowish brown (10YR3/4 + 10YR 5/6) silt loam; moderately developed fine polyhedral structure; weak soil strength; compact; very friable; 2% coarse stones; many fine roots
Bw	26-38cm	yellowish brown to dark yellowish brown (10YR 4/6-10YR 5/6) silt loam; weakly developed coarse blocky structure; weak soil strength; compact; friable; many fine roots
b B	38-68cm	light olive brown (2.5Y 5/6) heavy silt loam; moderately developed fine polyhedral and coarse blocky structure; slightly firm soil strength; compact; brittle failure; common fine roots
C	68-75cm+	light olive brown (2.5Y 6/2) sandy loam; apedal; compact; 55% coarse to very coarse stones