Soil Mapping, Compilation and Land Evaluation of Motueka, Riwaka and Moutere Valleys

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Abstract

The development of a soil map of the Motueka area, along with the supporting documents was completed during this study. This was achieved by the verification of an old poorly documented paper soil map. Primary Solutions Ltd initiated this project, but Tasman District Council provided the funding and assistance during this project. The project was developed as it was realized that there was significant potential for the map to be expanded and therefore better utilized.

Validation of the original map was done by auger observations during extensive fieldwork. It was found that the paper map provided a reasonably accurate portrayal of textural distinctions, but lacked definition for drainage classes. Some reclassification of the map was therefore undertaken, and two new soil series were developed (the Ferrer and Motueka) to compliment the existing seven series (Riwaka, Umukuri, Sherry, Maori, Hau, Braeburn and Tahunanui). Some areas of the Ferrer series still exist within the Riwaka series as they could not be extracted due tot eh timeframe of this study.

Soil physical and chemical analysis was also carried out on four of the most extensive and intensively used soils (Riwaka, Umukuri, Sherry and Ferrer). The Umukuri soil had the most suitable results from the tested physical factors, while the Riwaka came out as the poorest. The Riwaka was the most chemically fertile soil, while the Sherry was the least fertile.

Current land use in the study area (a total of 4355 ha) is dominated by apples (30% or 1261 ha) and pasture (28% or 1207 ha). Other horticultural crops with significant areas in the study area are kiwifruit (499 ha), hops (218 ha) and blackcurrants (87 ha). There is limited potential for expansion of the more intensive land uses onto pasture, as the pasture is generally located on stony or wet soils making them unsuitable for horticulture.

Land evaluation results demonstrated that all the sampled soils generally were well suited to hop, blackcurrant and kiwifruit. The Umukuri soil however was rated the most suitable, while the Sherry rated the poorest.

Acknowledgements

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Thank you to Alan Palmer for your guidance and supervision, this has been much appreciated. Also Dr. Iain Campbell, your assistance, expertise, and experience especially during the fieldwork gave me much reassurance.

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CHAPTER ONE

Introduction

Soil maps provide an insight into the distribution of soils within a selected area. Understanding this distribution is a significant benefit to land managers and others involved in land based decision making responsibilities. Soil is a very important and complex resource that can be easily damaged, but difficult, if not impossible to repair within the human time scale. Understanding the attributes and limitations of individual soil units therefore can assist in managing the soil resource.

While the identification of soils has been occurring for many thousands of years, the study of soils as an independent science is relatively new. The German scientist A. Fallou introduced the term 'pedology' in 1862 (Yaalon and Berkowicz, 1997), from which soil science has grown. Soil surveying was born in New Zealand in 1920 when Theodore Rigg together with J. Bruce carried out a survey of Waimea County.

Nationally, the coverage of New Zealand's soil resources is patchy. There are many publications between the scales of 1:1,000,000 and 1:50,000 that depict the distribution of soil from national through to regional scales. Soil publications at scales greater than 1:50,000 are rare. This is predominately due to the significantly higher costs and time involved with producing detailed maps. As land use and knowledge on the processes that contribute towards increasing production have intensified and increased, so has the need for such maps.

Soil maps for the Motueka area are currently inadequate for use by interested parties. The most detailed published soil map has a scale of 1:126,720 (Chittenden *et al.*, 1966).

Recently soil maps of various valleys within the region at scales as detailed as 1:15,000 have been rediscovered by the Tasman District Council (TDC), but lack accompanying documentation to enable their use. It is unknown who produced these maps that are no more than a sheet of paper with an unlabeled illustration. To utilise these assets it was recognised by Primary Solutions – an organisation set up to produce a Land Use Parameter Database for the Nelson Region - that documentation of these maps was needed. Jeremy Cooper (project co-ordinator of Primary Solutions) contacted Massey University on behalf of the TDC in an attempt to find personal who could undertake the documentation of the soil maps. This thesis was designed to meet this need.

1.1 Problem Statement

The TDC has various paper soil maps of the valleys within its region surveyed prior to 1951 but no documentation of the soil units. The TDC needs to know what each soil unit depicted on the map represents, and which soil units are significant for land use management decisions.

1.2 Aim

Produce a workable and meaningful soil map and supporting documents from detailed but poorly documented paper soil maps of the Motueka area.

1.3 Objectives

The objectives of this study are to:

1. ground truth the paper maps;
2. characterise soils on the paper map;
3. generalise the paper map where necessary;
4. create detailed soil map;
5. select four of the most extensive soils for detailed analysis;
6. provide recommendations; *and*
7. provide examples of applications of land evaluation.

CHAPTER TWO

Physical Resources of the Region

2.1 Location

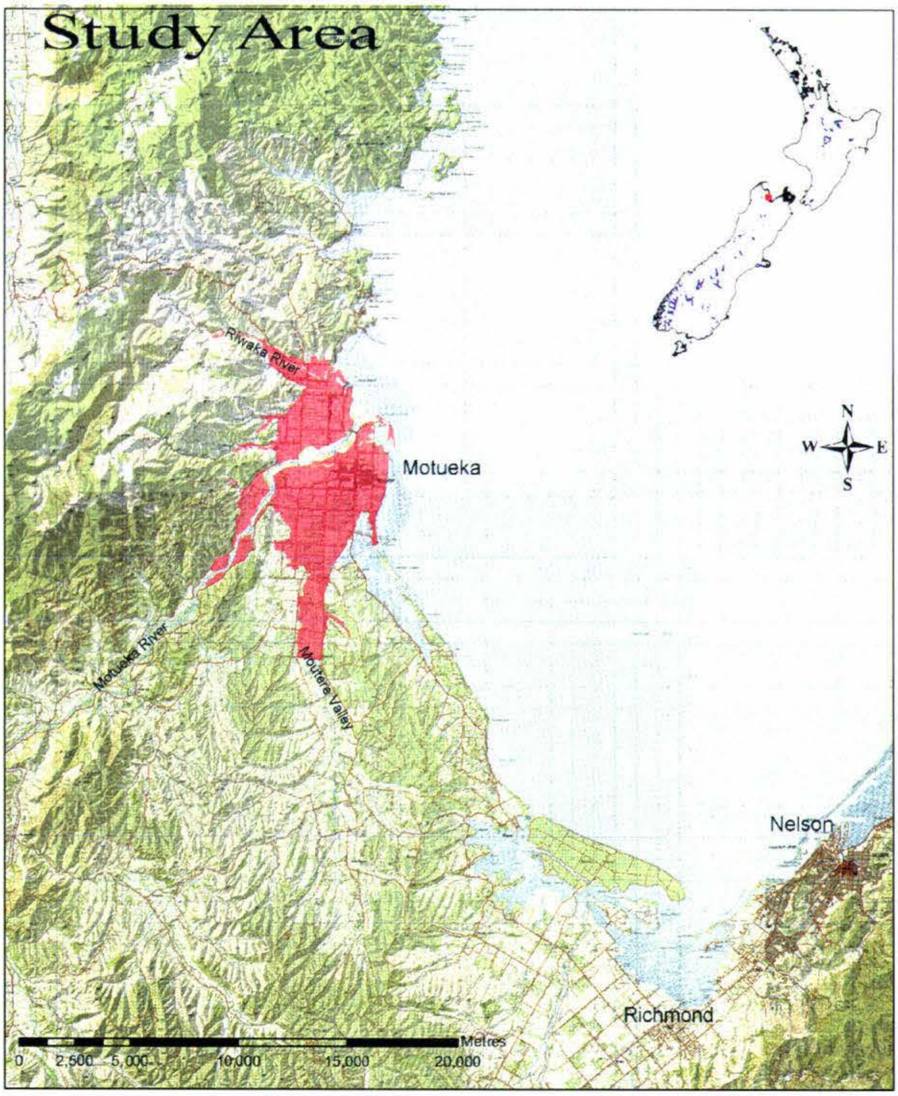

Figure 2.1. Extent of the existing soil map.

The study area encompasses the flat floors of the Riwaka, Motueka, and Moutere Valleys covered by the existing soil map (figure 2.1), an area covering approximately 4355 ha. The area sits on the Moutere depression, which is a collection of extremely deep (up to 2500m) gravels between the Richmond-Bryant Range and the Tasman Mountains formed during the uplift of the Tasman Mountains and Nelson Range (Rattenbury *et al.*, 1998).

2.2 Geology

The geology of the region is varied, but has been intensively studied and recorded. Detailed maps covering parts of the study area have been produced at a scale of 1:50,000 by Johnston (1982), and a scale of 1:63,360 by Grindley (1980) and Coleman (1981). The Institute of Geological and Nuclear Sciences Ltd. undertook the most recent compilation of the geology, during their QMap project (Rattenbury *et al.*, 1998). This publication gives a general description of the regional geology at a scale of 1:250,000, and is available in geographic information systems (GIS) format. This publication was produced by the generalisation of existing geological maps (primarily at a scale of 1:50,000 or 1:63,360) augmented by new data. It does not cover the entire Motueka Catchment as it excludes the headwaters region in the South, which will be included in the Kaikoura QMAP publication which is scheduled for publication in 2005. However, the headwater region is not significantly geologically different from the middle reaches of the catchment.

The Motueka River catchment covers a substantial area (approximately 2200 km^2) and has diverse, but distinctive geology (figure 2.2). The lower and mid (northern) region of the catchment is dominated by Early Cretaceous granites and Late Pliocene to Early Pleistocene gravels (Moutere Gravels) (Rattenbury *et al.*, 1998). The upper catchment is predominantly Early Permian ultra-mafic, and Triassic sandstone/siltstone units in the east. Ordovician limestone, marble, and middle Devonian calcareous mudstone dominate in the west.

The Riwaka Valley is geologically complex with several different units within the catchment (figure 2.2). The rock types are primarily Late Ordovician limestone (and marble) in the headwaters, Silurian schist, Late Devonian gabbro and clinopyroxenite in the mid valley, and Early Cretaceous granite towards the bottom of the catchment.

There are also numerous small side catchments where the sediments produced can be considerably different from those that form the general Motueka and Riwaka Catchments. An example is the small Brooklyn Valley catchment, where granites dominate the geology.

The Moutere Catchment is a very uniform catchment geologically, as it is entirely made up of the Moutere Gravels. These gravels are horizontally bedded, well rounded pebbles and cobbles of quartzose greywacke which are held within a clay-sand matrix. The age of the gravels is thought to be Late Pliocene to Early Pleistocene (Rattenbury *et al.*, 1998).

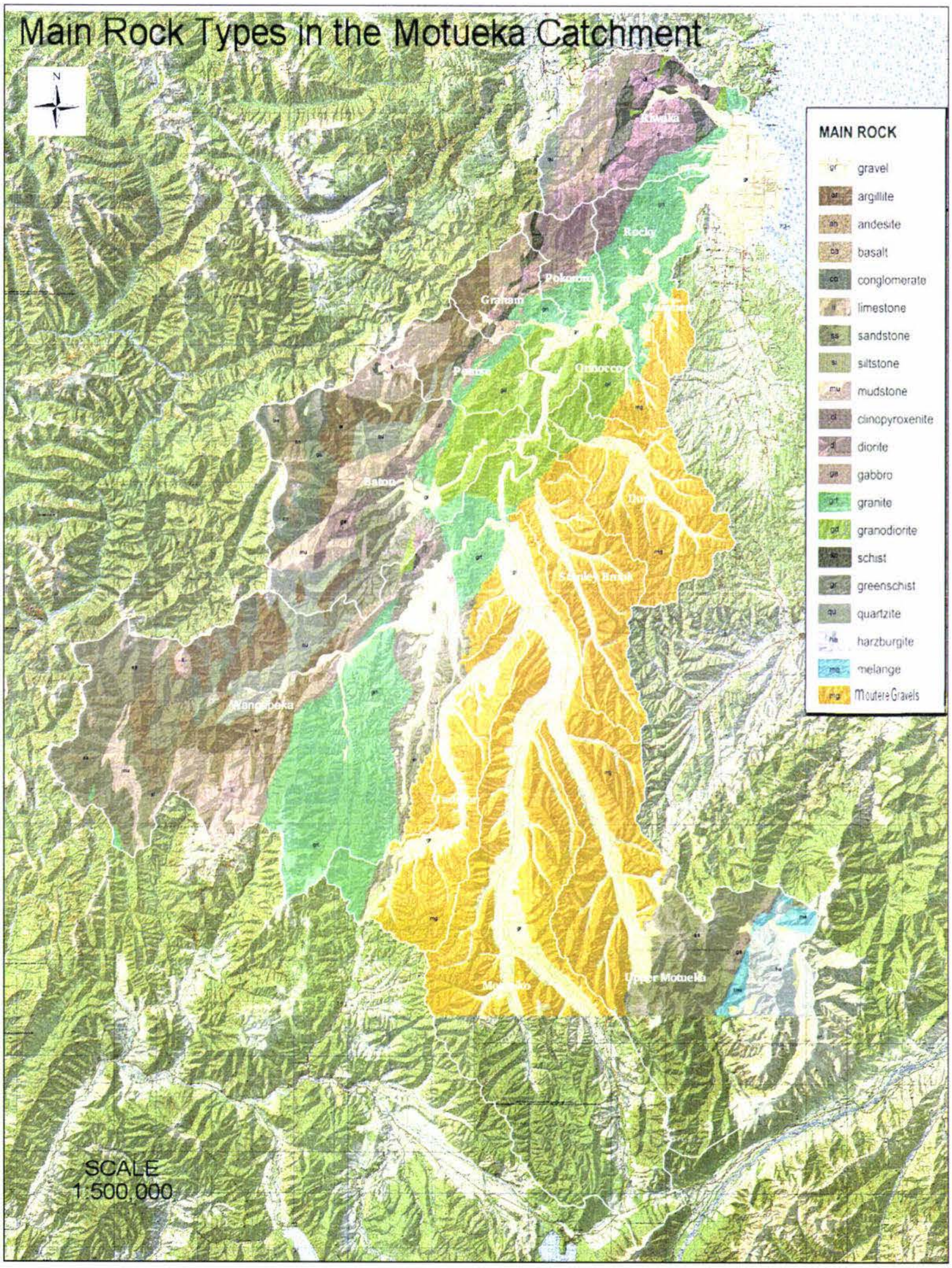

Figure 2.2. Geology of the Motueka and Riwaka Catchments (*adapted from* Rattenbury *et al.*, 1998).

2.3 Climate

The Nelson region is renowned for its sunny warm climate, with Motueka residents frequently claiming to have the best climate in New Zealand. The climate in Motueka is regionally distinct (figure 2.3), predominantly due to the effects of the surrounding mountain ranges.

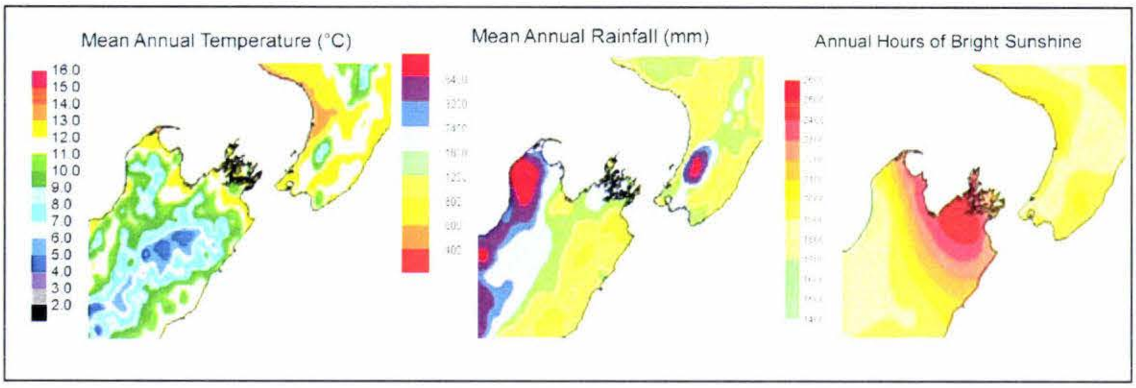

Figure 2.3. Climate summary of the region (*adapted from* Mackintosh, 2001).

There is little accessible recent climatic information, but there is plentiful published information for the period from the mid 1940's until the early 1980's. The 'Summaries of Climatic Observations to 1980' was compiled by the New Zealand Meteorological Service (NZMS) (1983). The climatic information discussed in this chapter is extracted from this publication unless referenced otherwise. There is also a climatic study currently being undertaken by a masters student, Glenn Waterland of Canterbury University. This study should provide an insight into the climatic variations that are occurring at selected locations within the Motueka area.

2.3.1 Temperature

The study area is very temperate, more like the North Island than the majority of the South Island. Mean annual temperature is 12.5°C at the Riwaka HortResearch site. Seasonal temperature variations are significant with January and February typically having the highest monthly means of 17.4°C, and July being the coldest month, with a mean temperature of 7.0°C. The annual mean daily range is also high at 11.1°C, and does not change much with the seasons.

In general, the temperature is warmer nearer the coast, while the valleys tend to be colder especially early in the morning and evening.

2.3.2 Rainfall

Annual rainfall in the Nelson region ranges from 950 mm at the coast from Ruby Bay to Nelson City, to over 5000 mm in the Ranges. Rainfall data collected by the TDC indicates that there is considerable local variation within the study area, with a low of 1200 mm at Moutere Inlet, and up to 1600 mm in the Riwaka Valley (figure 2.4). Generally as distance from the sea and/or altitude increases so does rainfall. Mean annual rainfall for the period between 1956-1980 at the HortResearch site on Old Mill Road was 1381 mm.

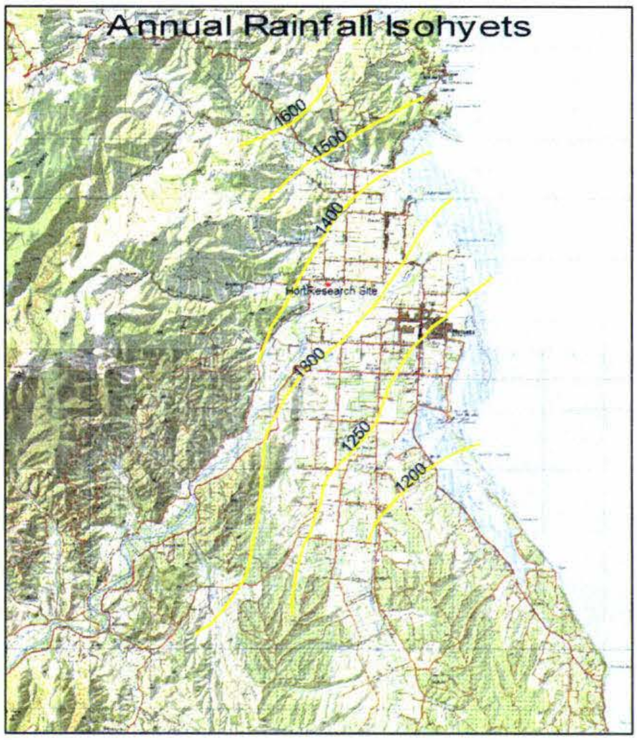

Figure 2.4. Rainfall Isohyets for the study area.

2.3.3 Sunshine hours

Sunshine hours in the study area are extremely high compared to the rest of New Zealand. This may be due to the effect of the surrounding mountains and the direction of the prevailing wind, which creates a zone of clear skies. Average annual sunshine hours are in excess of 2400 at the Riwaka HortReseach site. Monthly variations in sunshine hours are not great, but temporal summer months have more sunshine hours with January averaging 264, while the winter month of June has the least, at 146 hours.

2.3.4 Frosts

Frosts are common in the study area. Typically there are 82 days of ground frosts, and 31 days of air frosts at the Riwaka HortResearch site annually. The majority of the frosts occur during the months of May to September, with the greatest occurrence in July with an average of 19.3 and 11.4 days of ground and air frosts respectively. Frosts do not commonly occur in the months of November to March, with an average of only one ground frost during this period each year.

2.3.5 Wind

The lack of wind in the study area is a significant feature. Annually there is an average of 136 kilometres of daily wind run, compared to 646 at Wellington Airport (Goulter, 1984). Winter months are generally less windy with June and July having on average a wind run of 102 km, while November is generally the windiest month with a daily wind run of 174 km.

2.3.6 Evaporation

Pan evaporation is significant with an average of 1105 mm annually. This is likely to be due to the high levels of sunshine. January has the highest of 179 mm, while the lowest reading is typically in July with 27 mm. For the months between November and March levels of evaporation are greater than rainfall.

2.3.7 Other features

Annually there is on average half a day of snow or hail, 1 day of fog, and only 0.1 days of gale force winds. Winter (1^{st} May-30^{th} August) chilling units for Riwaka during 1998-2002 range between 1176 and 1442 (Snelling and Langford, 2002).

2.4 Previous soil studies

The Nelson region hosted some of the earliest soil science in New Zealand. Sir Theodore Rigg of the Cawthron Institute in Nelson carried out numerous studies of soils in the region as early as 1920, including a survey of Waimea County (Rigg & Bruce, 1923). At this time the science of pedology was in its infancy and the methods of soil classification and mapping were developing rapidly. Many of these initial studies have provided the information on which the more recent soil maps of the region are based.

2.4.1 Bulletins and reports

In Soil Bureau Bulletin 30, 'Soils of the Waimea County, New Zealand' (Chittenden *et al.*, 1966), the soils are classified in a significant amount of detail. This publication and accompanying map at a scale of 1:126,720 divide the study area into six different soil series. Three of the soil series are monotypic while the remaining three are differentiated into two soil types. The soil types are the:

- 'Riwaka silt loam and sandy loam', and the 'Riwaka silt loam (wet phase)';
- 'Maori gravelly sandy loam';
- 'Sherry sand and sandy loam';
- 'Braeburn clay loam', and 'Braeburn sandy loam';
- 'Tahunanui sand', and 'Tahunanui sand and gravel'; *and*
- 'Hau stony sandy loam'.

There is a brief typical profile description of each soil type provided in the bulletin, with information on the parent material. There are also limited chemical analyses of the soils with tests such as pH, phosphorus retention, organic matter, cation exchange properties, potassium supplying power, and acid soluble magnesium. Recommendations for fertiliser applications on each soil are also mentioned. This publication is currently used as the main source of soils information by local bodies and interested parties when making land use management decisions.

The Soil Bureau also completed other reports in the region, primarily by the pedologist Michael D. Laffan. One such report was 'A report on a soil investigation of hops in the Nelson Region', an unpublished report produced in 1975. The report and field sheets, which are held by Landcare Research, provide a good description of the more productive soils of the region. Information includes detailed soil profile descriptions of all the hop gardens in existence in 1974. The soil variability in each garden is also often discussed. The report itself discusses and compares the hop yields on the differing soil types. It finds that hops produce the highest annual yields on the Riwaka sandy and silt loams (soils from composite parent materials derived from greywacke, granite, limestone, quartzite and basic igneous rocks), where 2400kg/ha of seedless hops were produced. The Braeburn silt loam and sandy loam (soils with alluvium derived entirely from Moutere Gravels) produced significantly less hops, with average annual yields of only 1350kg/ha. Soil parent material, which effects nutrient status, was attributed as the main factor for these differences.

A published report by Laffan (1988) entitled, 'A report on the soils of Umukuri Farm, Riwaka', describes the soils on the property directly east of the current HortResearch site on Old Mill Road, at a scale of 1:4,000. This report made use of the soil series units from the Soils of the Waimea County (Chittenden *et al.*, 1996) publication, and portrays the differing textural and mottling distributions found during auger observations. The soil types displayed and described are the Riwaka sandy loam, Riwaka shallow sandy loam, Riwaka mottled fine sandy loam, Sherry sandy loam, and Sherry mottled sandy loam. Detailed profile descriptions of these soils are included. This is the only known published source of detailed soil profile descriptions of some of the soils in the study area. There is no new information on the physical and chemical characteristics of the soils.

The oldest documented soil investigation found during this masters study was 'The Maori Gravel Soil of Waimea West, Nelson' by Rigg and Bruce (1923). This report discusses the possible methods the Maori people used to augment soil, as well as a physical and chemical description of the soil. While this publication describes the Maori soils in the Waimea Plains it is noted that they are very similar to those near Motueka. It is suggested in this report that these soils were formed as a result of modification for the production of sweet potato (kumara). This was done by the addition to the soil profile of gravels and sands, and charcoal obtained by burning imported vegetation. This practice had a marked impact on the soil, especially the chemical fertility. Analysed soils had a significant increase in plant available phosphoric acid.

2.4.2 Papers and journal articles

As mentioned in Chapter One, it is unclear who and when the paper map was produced. There was only one publication found during this study that gave an overview of all the soils on the existing paper maps. This was a short paper entitled 'Soils of the Nelson District' by Sir Theodore Rigg, which was read to the Grasslands Conference, Nelson, in November 1954. In the paper each soil in Waimea County is discussed, but particular attention is placed on those used for agriculture. There is a fairly comprehensive description of the parent material of each soil as well, but little on other physical characteristics. Chemical deficiencies including cobalt, boron, copper, molybdenum and magnesium are discussed.

Rigg and Chittenden (1951) wrote an insightful article entitled 'Classification of land in the Waimea County, Nelson, for flue-cured tobacco'. In this article a description of how the soils were classed and grouped is explained in some detail. It initially divides the alluvial soils in the Waimea County into six soil series based solely on parent materials (and thus consequently on chemical fertility). A description of the parent materials for each soil series is given. The soil series mentioned are the Riwaka, Waimea, Sherry, Tapawera, Motupiko and Maori. Each series is then divided into six more subclasses, or soil types as follows.

1) Well-drained fine sands and sandy loams of good depth and not subject to river flooding. The depth of fine sand should be not less than 18 inches (46 cm) unless underlaid by sandy loam.
2) Somewhat similar to those in subclass 1) but with textural conditions less perfect, e.g. underlying horizons rather too heavy or alternatively too open.
3) Gravelly sandy loams and sands with rather open subsoils. This group of soils is satisfactory if irrigation can be practised but otherwise the tobacco crop is detrimentally affected by drought in dry seasons. Included in this category are certain soils liable to occasional flooding.
4) Soils of a somewhat "heavy" texture for high quality tobacco, and gravelly silt loams and light phase silt loams. Good yields are associated with tobacco culture on these soils but the leaf is frequently of comparatively poor quality, particularly in years of high rainfall. Soils of this textural class, belonging to the

Motupiko series with lower inherent fertility, have given much better results in so far as quality of leaf is concerned. It is also the case with heavy soils belonging to the Riwaka series

5) Soils which are texturally too heavy for flue-cured tobacco. These are silt loams and light phase silt loams, underlaid by a heavier textured subsoil. They may possibly have some value for air-cured or fire-cured but not for flue-cured tobacco.
6) Soils which are quite unsuitable for tobacco culture. These include clay loams, stony loams, and peaty soils with a high water table.

These criteria were used to produce maps to spatially depict the occurrence of each unit. These maps therefore are not true soil maps, but more, suitability maps for the production of flue-cured tobacco. These maps may still exist today, and may clarify some of the unexplained additional paper soil maps of the region, currently held by the Tasman District Council.

An investigation into the physical and chemical properties of the Maori gravel soil was undertaken by Challis (1976). This study had four objectives, which were:

1. to examine the soil B and C horizons to test the theory of gravel addition;
2. to prove the presence of a gravel quarry pit;
3. to test for any residual effect on soil mineral content on the process causing the dark soil coloration; *and*
4. to determine the effect of the additional gravel on soil temperature.

The author concluded that the addition of gravel was done by early Maori settlers, and that the gravels were quarried from a nearby pit. Charcoal found in the soil pits was also analysed and found to be of rimu origin that was dated at 830 (plus or minus 60) years before present. The chemical analysis that compared the Maori soil with an adjacent unmodified soil concluded that there is no residual chemical enhancement of the soil. However, the soil temperature of the Maori gravel soil was found to be greater than the unmodified soil. The author discusses the implications of growing kumara, and concludes that the gravel soil would extend the growing season by up to one week.

2.5 Historical Vegetation

Before European arrival much of the Nelson region was covered in forest. Beech (*Nothofagus spp.*) forest dominated the steep slopes, while podocarps were abundant in the higher rainfall areas, gullies and on the lowlands (Chittenden *et al.*, 1966).

The Moutere Valley and lower lying land around Motueka and Riwaka was forested, but swampy and commonly flooded. The area of stony soils to the south-west of Motueka township was not forested and supported manuka (*Leptospermum* spp.), bracken (*Pteridium* spp.), and grasses. Many of the other valleys up the Motueka River were heavily forested, with the exception of some of the areas of dry stony soils above Tapawera, where manuka, matagouri (*Discaria toumatou*), and grasses dominated.

Maori settlement in the area did have a significant impact on pre-European vegetation. Much of the coastal belt near Motueka was deforested. This is thought to be due to the area having been burnt off, and the low rainfall causing a slow rate of reforestation (Chittenden *et al.*, 1966).

2.6 Land use

Figure 2.5. Intensive land use about Brooklyn, looking east along Old Mill Road.

The study area has a favourable climate, with high sunshine hours, moderate rainfall, and lack of winds, and therefore is highly suited to a many horticultural crops. Land use in the study area is intensive, with little suitable bare land left for further development (figure 2.5 and figure 2.6). Changes in land use would generally involve the replacement of one intensive crop for another. While there are significant areas of pasture, much of this land is on the less suitable soils, which have limitations such as excessive or poor drainage.

Land uses within the area covered by the soil map were collated during this study (figure 2.6). Observations were taken during the fieldwork and later digitised. Land use areas can be calculated from this, and correlated to soil series (Table 2.1). It must be noted that these land use areas do not contain roads, so there is a slight discrepancy (10 ha) between total areas discussed in the soil survey report (chapter 7).

	Ferrer Soils		*Hau Soils*		*Motueka Soils*		*Maori Soils*		*Braeburn Soils*		*Tahunanui Sands*		*Umukuri Soils*		*Riwaka Soils*		*Sherry Soils*		**TOTAL**	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Hops	17	6	0	0	3	2	10	12	0	0	0	0	32	11	150	8	6	3	**218**	**5**
Apples	48	17	305	39	48	38	23	27	171	33	8	5	96	34	517	28	45	21	**1261**	**30**
Pears	0	0	0	0	0	0	0	0	0	0	0	0	17	6	19	1	4	2	**40**	**1**
Kiwifruit	10	4	131	17	11	9	17	20	1	0	8	5	32	11	260	14	29	14	**499**	**12**
Pasture	136	47	160	20	46	36	9	11	314	60	8	4	52	18	382	21	91	43	**1207**	**28**
Currents	1	0	12	2	2	2	3	3	0	0	0	0	11	4	58	3	0	0	**87**	**2**
Grapes	0	0	14	2	6	5	2	3	0	0	0	0	0	0	27	1	0	0	**49**	**1**
Citrus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**0**
Research	0	0	0	0	0	0	1	1	0	0	0	0	12	4	18	1	0	0	**31**	**1**
Olives	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**
Buildings	11	4	31	4	9	7	13	15	21	4	7	4	26	9	128	7	21	10	**267**	**6**
Town-Motueka	47	16	125	16	0	0	5	6	0	0	137	77	0	0	236	13	0	0	**550**	**14**
Roses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0	0	**14**	**0**
Raspberries	0	0	1	0	1	0	0	0	0	0	0	0	0	0	5	0	0	0	**7**	**0**
Market Garden	1	0	0	0	0	0	3	3	0	0	6	4	0	0	14	1	13	6	**37**	**1**
Trees	11	4	2	0	2	2	0	0	18	3	4	2	8	3	21	1	3	2	**69**	**2**
Gravel Extraction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	**5**	**0**
TOTAL HA	**291**		**782**		**128**		**86**		**526**		**178**		**287**		**1855**		**213**		***4345***	

Table 2.1. Land uses and distribution on differing soil series in the Motueka area.

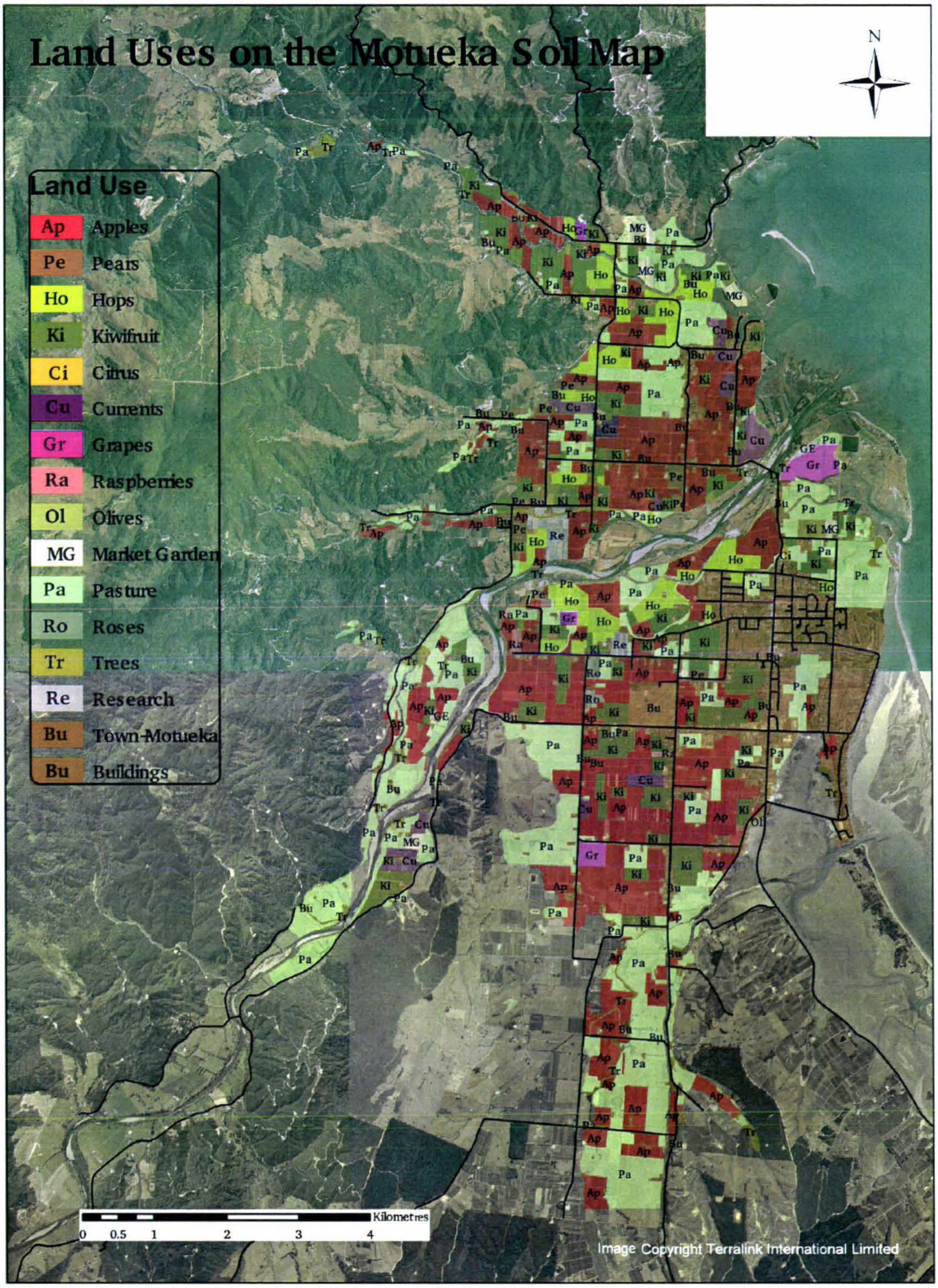

Figure 2.6. Land uses on the Motueka soil map area.

2.6.1 Early Maori Agriculture

The impacts of pre-European agricultural practices are still evident in the Motueka and Riwaka areas. There are significant sites where there have been modifications to the landscape, particularly by the addition of gravels and/or sand and burnt vegetation to the upper soil profile (Challis, 1978). The assumed reasoning for this is that it was an attempt to increase the fertility, drainage, soil temperature and moisture storage to enable the growth of tropical food crops such as kumara, gourd, taro and yam (Chittenden *et al.*, 1966; Green, 1975; Challis, 1978).

2.6.2 Tobacco

Tobacco was once the dominant crop grown in the Motueka area, peaking at 763 growers and 2379 ha in the 1963-64 season (O'Shea, 1997). H. Everett produced the first commercially grown crop at Umukuri in 1888, but the industry did not flourish until 1916 (Gregory, 1976). The demand for this crop began to decline as cigarette companies found cheaper, better quality leaf elsewhere. Rothmans, the final company with contracted growers finally pulled out in 1996, putting an end to this once profitable crop. The legacy of the once strong tobacco industry can still be seen with the many abandoned kilns scattered around the countryside.

During the period of maximum profitability of the tobacco crop, many properties were subdivided into small units to provide separate lots for the owner's siblings. This was a common practice as the financial returns for tobacco were so great. The result is that now the countryside is subdivided into small holdings, with few continuous sizeable tracts of productive land.

2.6.3 Hops

The climate of Motueka is well suited to the production of hops. Hops have been grown now in this area for over 150 years, and have been selected through extensive research to become some of the best varieties worldwide. This is due to the high proportion of alpha resins, which are intensely bitter and responsible for the desired bacteriostatic contribution to beer (MAF, 1997).

Many of the growers have invested considerable amounts of capital into processing of hops. Hops are harvested and transported to an onsite processing plant which generally consists of picking machines that strip the hop cones from the vines, cleaning belts to remove leaves and excess vine, and drying systems where kilns are used for drying the hops.

Hops currently occupy 218 ha (5%) of the study area. The majority of the gardens have been grown at the same location for many years. Due to the high set up and post harvest costs the introduction of new growers into this industry is slow. Many of the current growers do not solely grow hops and this land use is generally combined with apples.

The recent development of the supercritical CO_2 extraction plant in Nelson is a huge advantage to the hop industry. This joint venture between NZ Hop Products Ltd and Nutri-Zeal Ltd, removes the need to transport comparatively bulky hop pellets to the Northern hemisphere for processing, with jars of resin produced instead. This development may assist in reinvigorating the hop industry in New Zealand.

2.6.4 Apples & Pears

The history of apple production in the study area is long and distinguished. Research into the growth of apples has been occurring for some time, but has been traditionally concentrated on the Moutere gravels. Apple orchards were grown as far back as the 1850's, and participation in this land use has increased from there. While the rainfall in Motueka is quite high for the production of apples, this is partially offset by the high sunshine hours.

These crops (primarily apples) represent the major land use in the study area at the present time, totalling some 1301 ha or 31% of the study area. This area is significantly greater than any other intensive land use. It also equates to more than half of the apple orchards in the Tasman District (Statistics New Zealand, 2003).

2.6.5 Kiwifruit

The production of kiwifruit in the Nelson region has increased from eight hectares in 1975 (Hadfield, 1982) to one of the dominant crops in the study area. When the production of kiwifruit in New Zealand had poor financial returns in the early 1990's, significant areas of this crop were removed and put into other land uses. However, since then kiwifruit production has again increased.

Kiwifruit is extensively grown around Motueka, and currently occupies 499 ha, making it the second biggest horticultural land use in the area. There are significant areas of the new Zespri variety of kiwifruit, with the majority of the recent plantings being this variety.

2.6.6 Berries

Berries, particularly raspberries, have been grown in Motueka since the 19th century, and include most of the original plantings in New Zealand (MAF, 1998). Details on the historical statistics of raspberries in New Zealand are unclear and unreliable with many discrepancies (MAF, 1998). It is evident, however, that the Nelson region provides a significant proportion of the national raspberry crop.

Current levels of berry production were found to be minimal within the study area. In total there was only seven hectares identified as being in berry production. The main type of berry grown is raspberry.

2.6.7 Blackcurrants

Historic data on the blackcurrant production in the Nelson indicates that this was never a prominent land use. Langford and Mavromatis (1981) reported that total numbers of growers in the Nelson/Marlborough region peaked at nine between the seasons of 1975/76 to 1979/80. The area planted by these growers was small, reaching a maximum of 37 ha in the 1979/80 season.

Blackcurrants are now a significant land use, occupying 87 ha. While this area only equates to two percent of the study area, the land use is the fourth most dominant.

Currants are grown in five large areas, which is rare for land uses in the study area. The current end uses for blackcurrants are varied, including jams, juices, frozen and pies.

2.6.8 Vineyards

A limited number of small scale vineyards have recently been developed within the study area. This is possibly due to the highly productive nature of the area, and the already established land uses (i.e. apples). In total there are 49 ha of viticulture in the study area. The viticulture growth that has that has been occurring in New Zealand over the last ten years has been primarily replacing pastoral land uses. Vineyards, in general, are well suited to poorer gravelly land where the soil has low moisture holding capacity. This enables the grapes to be stressed and flavour and quality of the wine controlled. There may be a possibility that current areas in pasture may be converted into vineyards in the near future, especially on the stony Hau soils. However, the effect of frosts (especially late and early) must be investigated further.

2.6.9 Market Gardens

Market gardens used to be plentiful around Motueka due to the extended growing season, and the regions competitive access advantage to the South Island produce market. Numbers, though, have been decreasing due to the increased efficiency of transportation, which has allowed produce from as far away as Pukekohe to easily reach the South Island. The variation of soil type and microclimate within paddocks has also made it difficult to achieve uniform crop ripening. The relatively small size of the paddocks in the study area (compared with areas such as Pukekohe) has also meant that the potential for significant operations to develop is low.

There are still a few small market gardens around Motueka, but numbers have been decreasing. Market gardens now occupy only 37 ha of the study area.

2.6.10 Green Tea, Boronia Oil, Medicinal Herbs

There was a large effort to establish these crops in the Nelson region during the early 1990's. Today none of these crops are being commercially grown. Their failure was primarily due to inadequate awareness of the significance of climate data, particularly the failure to recognise the effect of the high ultraviolet levels, and the early and late frosts.

2.6.11 Pasture

Pastoral farming was previously a far more significant practice in the study area. Dairy farming was common, but now the only remnants are the derelict milking sheds scattered throughout the plentiful orchards. This change in land use can probably be attributed to increased drainage of the wet soils, which has made the land suitable for an intensive horticultural use.

Most of the remaining pastoral land is used for sheep and beep production on poorer soils that either have a wetness or stoniness limitation. There are still 1207 ha of pasture in the study area, with the majority of this further up the Moutere and Motueka Valleys.

CHAPTER THREE

Revision of the Soil Classes

3.1 Approach

Validation and interpretation of the existing soil map was needed as it was not being utilised to its potential, and its accuracy was unknown. There was also no workable legend with which to interpret the map. This study aims to resolve these problems.

The existing old paper soil map was digitised by the Nelson City Council, and the completed shapefiles were provided to the TDC.

Initially an introductory letter was sent out to all landowners in the study area advising them of the project and requesting permission for access to their properties. There were mainly affirmative replies to this request, along with a few refusals. The properties that allowed access were surveyed first, and areas where further studies were needed were followed up and access duly obtained.

It was decided that instead of trying to complete a comprehensive coverage of the entire study area (beyond the scope of a one year masters study), that intensive examinations of selected properties would be more beneficial in achieving the goals set. A detailed inspection of selected individual properties would assist in determining the variability of the soil types, as well as providing comprehensive soil descriptions for the existing map units. The amount of time available for fieldwork was also a consideration into determining this approach.

3.2 Methods

3.2.1 Map Validation

Fieldwork was undertaken with the following equipment:

- A 1:5,000 scale field sheet with the digitised existing soil map draped over a recent (2002) colour orthographic aerial photograph
- A dutch auger with a total length of 120 cm, and an auger diameter of 75 mm
- A spade
- A Munsell soil colour book
- A digital camera
- A field notebook

The intensity of surveying on each property was determined by factors such as their size, topography, and soil units suggested by the existing soil map. Smaller properties were intensively surveyed in a grid-like manner. Where topography obviously changed, additional sites were selected to try and obtain a better understanding of the soil pattern, resulting in areas of concentrated sampling. A lower sampling intensity was used where the topography was uniform and the existing soil map indicated that there was little variation in the soil type.

Where a sample was taken the profile was described in the field notebook, noting thickness of horizons, texture, colour, presence of stones/gravels, presence and abundance of mottling (both low and high chroma), and any other noticeable features. The sample was laid out to enable an assessment of the depth of features. A photo was taken of typical samples and where something unknown was occurring. The location of the sample site was also noted on the field sheet. This location was later digitised into GIS form back in the office (appendix A1).

3.2.2 Land Use Map

A land use map was produced which can be used at a scale of up to 1:20,000. This was done from observations during the soil mapping fieldwork. These observations were noted onto field sheets at a scale of approximately 1:10,000, and later digitised at the Tasman District Council, or the New Zealand Centre for Precision Agriculture (NZCPA) at Massey University.

3.2.3 Soil Description and Sample Collection

Four sites were selected for further detailed examination. These sites covered a dominant soil type from the four series with the greatest productive potential, namely the Riwaka, Umukuri, Sherry and Ferrer series (new series name see section 8.3.2). The Hau, Maori, Braeburn, Motueka (new series also see section 8.3.2), and Tahunanui series were therefore not examined. The Hau soils was not sampled due to it being very gravelly; the Maori due its variability from site to site, and small representation; the Braeburn due to poor drainage and current limited land uses; the Motueka due to its gravelly limitation and small representation; and the Tahunanui because it is mainly occupied by Motueka Township and also because of its limitations due to low water holding properties and salinity problems.

A pit was dug at these selected sites to a depth of at least one metre. The soil profile was described noting thickness and depth of horizons, colour, texture, structure, roots, mottles, boundaries and any other noticeable features. Samples were collected from each horizon for chemical analyses (bulk sample), and physical analyses (standard sampling rings for bulk density, hydraulic conductivity, and water retention). Four replicate samples were collected in each horizon for the physical data. A further sample for chemical analysis was obtained by taking 10-15 10 cm long cores within 25m of the soil pit, using a soil sampling corer with a diameter of 2cm.

3.3 The Problem With Old Classes

The soil classification that was being used in New Zealand when the old paper map was produced, the New Zealand Genetic Soil Classification, (Taylor, 1948) is different from that which is used today, the New Zealand Soil Classification (Hewitt, 1998). The old soil classes were less rigorously defined than the modern ones. Today more research has been done into the precise factors that dictate plant growth. Variables such as depth to gravels or water table, and the presence of impeding features such as pans have been considered in defining new classes.

The precise criteria used in determining the different classes on the old soil map are not known, as there is no accompanying legend. This study will attempt to provide criteria. The labels used to describe some of the different soil classes are also unclear. Names such as 'light phase', could imply a number of differing soil factors, and are not considered helpful today.

3.4 Definition of Soil Series: Concepts

Soil can be categorised and distinguished on both pedological and physiographic features. These are features such as differences in parent materials, profile form (nature and sequence of horizons), specific environmental conditions, and sometimes by the nature of the landform where the soil is found (McLaren and Cameron, 1996). This can lead to the development of a hierarchical soil classification.

3.4.1 Parent materials

The distribution of parent materials is generally the initial factor (if there is no significant variation in climate) for defining soil classes in the landscape. As this study area is concentrating on the flat land around Motueka, the majority of the soils are derived from the recent alluvial material from the many rivers and streams in the area. The parent material that has formed the plains from each of these watercourses reflects the geology of the catchment area. The parent materials from the main Motueka Catchment are principally formed from a great variety of alluvium from predominantly greywacke, quartzite, limestone, granite and basic igneous rocks. The parent material from the Riwaka Catchment is similar to that of the Motueka Catchment, but the concentration of ultra mafic rocks is higher. Some of the small sub catchments off the Motueka Catchment produce markedly different parent materials, e.g. greater proportions of granite. Early soil studies in New Zealand focused on parent material in the absence of different landforms. Commonly in an alluvial setting (especially in the Manawatu and Canterbury) there are suites of Holocene terraces that are formed as rivers cut down into the landscape. These terraces assist with the classification of soil series units, but are largely absent within the study area.

Due to the study area's close proximity to the coastline, coastal sands are also found and are easily defined on landform and texture.

3.4.2 Profile form

Soil profile form is another way to classify a soil. The key features that differentiate the soil are drainage classes, depth of profile of loamy or sandy material over gravels, and texture. These factors greatly impact on the management and land use limitations.

The drainage class has a significant affect on possible land uses and therefore recognising the extent and type of drainage impediment is very important. Drainage class is defined by the number of low chroma (grey) mottles in the profile, with two percent as the cut off point (figure 3.1). Well drained soils have a profile where the upper 80 cm or more is free* of grey mottles. Moderately well drained soils are free of mottles in the top 60 cm. Imperfectly drained soils have common grey mottles below 40 cm, and poorly drained soils have grey mottles up to and within the topsoil. The drainage classes can be used to define series, and in this study well drained and moderately well drained soils are put into separate series, with imperfectly and poorly drained soils forming a third (figure 3.1). Defining series in this way is justified both by the land use implications and contrasting soil forming processes.

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* in this case "free" means less than 2%

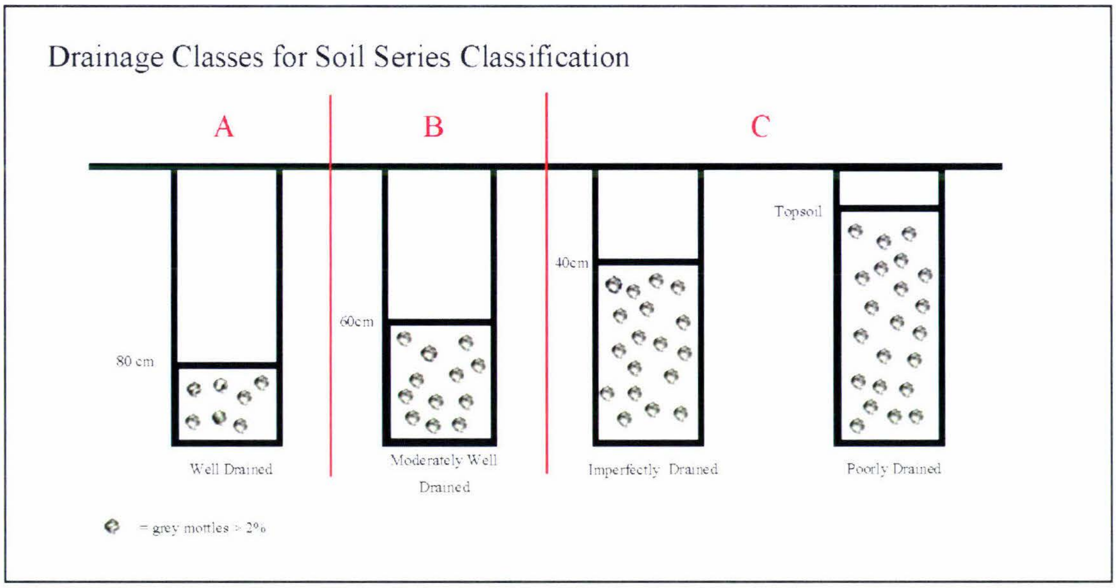


Figure 3.1. Drainage classes for soil series classification (Palmer, pers. comm., 2003).

Soil depth is another factor that is used to group soils (figure 3.2). The depth is generally measured to gravel, but also can include any other impeding layers or limiting factors such as an impervious pan or coarse sands. Soils deeper than 20 cm are generally arable while those that are less than 20 cm may not be.

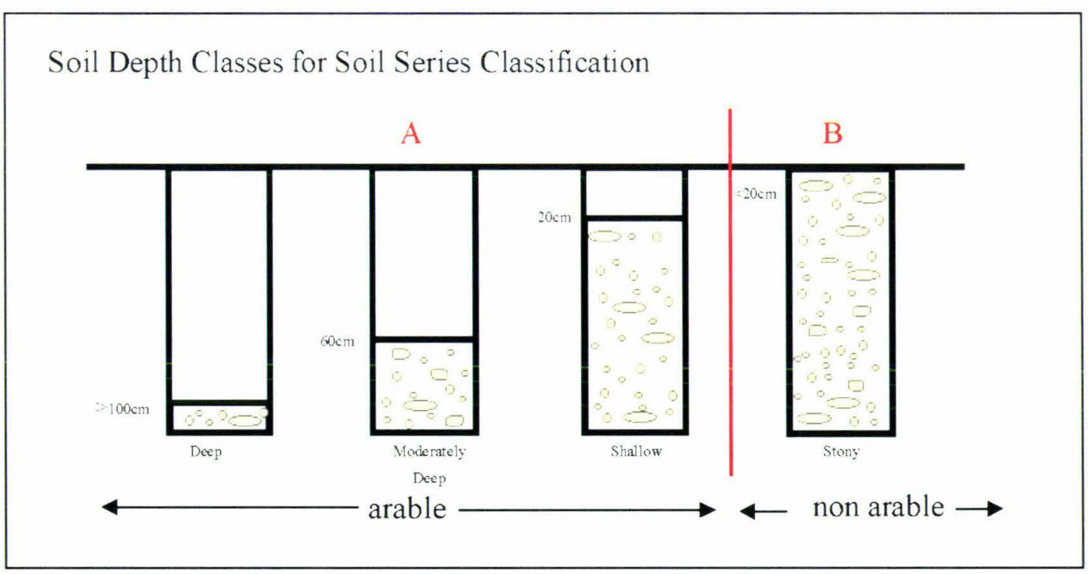


Figure 3.2. Soil depth for soil series classification (Palmer, pers. comm., 2003).

3.4.3 Environmental conditions

Environmental conditions such as rainfall and temperature can have an impact on soil formation. Rainfall affects the rate at which the soils are weathered, and the rate at which leaching occurs. Temperature affects the rate of chemical reactions and also the rate of vegetation growth. A warmer temperature increases the rate at which chemical reactions occur. A 10°C increase in temperature increases chemical reactions involved in weathering two to three fold (McLaren and Cameron, 1996).

The differences in environmental conditions within the study area are not great, and consequently do not enter into the differentiation of soil series.

3.4.4 Nature of the landform

Different landforms and parts of landforms often have different soils. River and stream valleys often produce a variety of flood plain landforms, low terraces and their risers, and bars and channels. In areas of uplift, the river may cut down through the surrounding land and leave a terrace suite as it changes course. Terrace A (figure 3.3) is the youngest terrace and is often flooded. The soil profile on this terrace is therefore very young and generally only consists of an A and C horizon. Terrace B is slightly elevated above A and is only rarely flooded. The soil profile has had more time to develop on this terrace, and a Bw or Bg horizon is also present. The C terrace sits higher again in the landscape and is no longer flooded. The soil profile on this terrace is more developed, and a C horizon is only found at depth. On each terrace, areas of impeded drainage may develop, and be reflected in the resulting soil profile (figure 3.3).

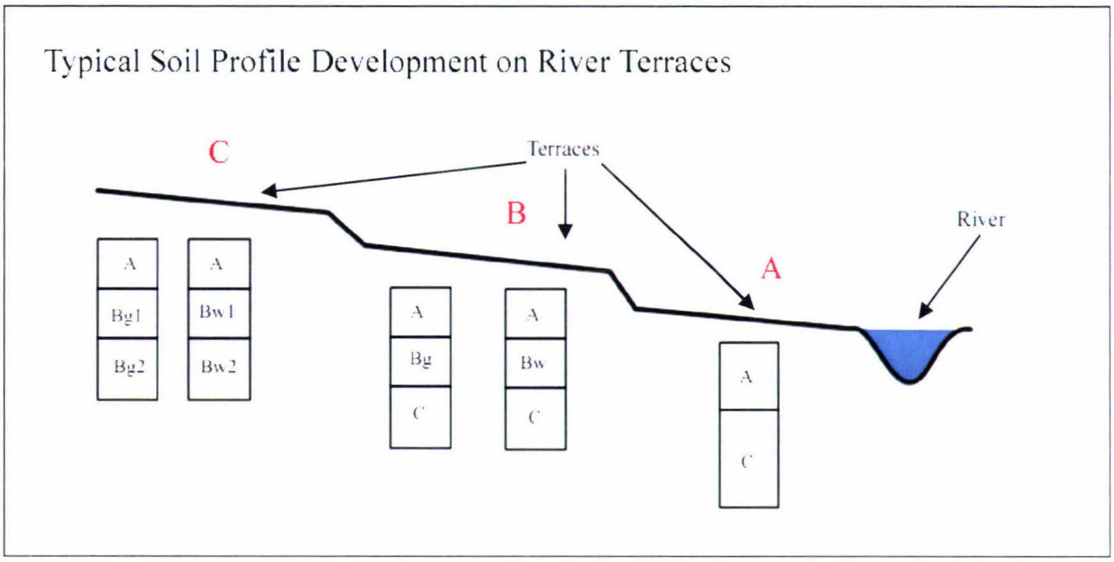


Figure 3.3. Typical soil profile development on river terraces.

In the study area there is little evidence of discrete low terraces, and differentiation of soils in this manner is not possible. Also stop banks designed to eliminate flooding were erected in the 1940s and 1950s, largely stopping deposition of sediments outside the stop banks.

Coastal sand dunes also form a distinct landform in the study area. The dune morphology is reasonably easily distinguished and is found in a ribbon pattern along the coastline. The low lying coastal sands are more difficult to identify by landform observations as they merge into the surrounding alluvial soil. Identification is therefore achieved by auger observations.

3.5 Soil Types

The main source of information on the soils in the region is the "Soils of the Waimea County, New Zealand" (Chittenden *et al.*, 1966). This publication includes the 'Riwaka silt loam and sandy loam', 'Riwaka silt loam (wet phase)', 'Maori gravelly sandy loam', 'Sherry sand and sandy loam', 'Braeburn clay loam', 'Braeburn sandy loam', 'Tahunanui sand', 'Tahunanui sand and gravel', and 'Hau stony sandy loam'.

The following account is paraphrased from Chittenden *et al.* (1966).

The Riwaka silt loam and sandy loam is described as a soil formed from a variety of rocks which include greywacke, quartzite, limestone, granite and basic igneous rocks at Motueka and Riwaka. Soils tend to be thin near rivers with occasional gravelly layers in most places. Fertility is moderate to high, slightly acidic, high phosphorus, medium calcium and low potassium.

A typical profile is:

10 in. (25 cm)	greyish brown silt loam, very friable, moderately developed coarse nutty and fine crumb structure;
10 in. (25 cm)	dull greyish brown fine sandy loam, friable, weakly developed coarse blocky structure;
12 in. (30 cm)	pale brown sandy loam, loose, structureless;
on	sand and gravels

The Riwaka silt loam (wet phase) is found in small low lying areas near the coast. The land is close to sea level, and this is the major cause for this soil having drainage problem. These soils have greater amount of organic matter in the topsoil and therefore have a darker colour. Mottles and gleying are common in this soil, and gravels usually occur below 3 feet (90 cm).

The Maori gravelly sandy loam is described as sites where Maoris made kumara beds prior to European settlement. This soil has sands and gravels as well as charcoal in the upper horizon due to the modifications the Maori people made. Topsoils are 25-30 cm deep, and are dark grey or black. Subsoil is typically unaltered. The distribution of this soil is scattered, predominantly on the higher ground above regular flooding. The profiles of these soils vary with locality. The fertility of these soils is high.

The Sherry sand and sandy loams are derived from granite alluvium, and are found at Riwaka, Umukuri and scattered locations along the Motueka River system. Texture and depth to gravel varies greatly, but medium sand is the most common texture. Soils are especially shallow and coarsely textured near rivers and streams. Fertility is low in this soil.

A typical profile is:

6 in. (15 cm)	pale brownish grey medium sand, very friable, weakly developed fine granular structure;
6 in. (15 cm)	greyish brown medium sand, very friable, weakly developed medium blocky structure;
9 in. (23 cm)	pale yellowish brown medium sand, loose, structureless;
on	sand.

The Braeburn clay loam soil is derived from weathered Moutere Gravels, and is found up the Moutere Valley. Typically these soils are strongly gleyed, with an impervious iron pan sometime present. Fertility is very low.

A typical profile is:

8 in. (20 cm)	brownish grey clay loam, firm, strongly developed coarse blocky structure;
4 in. (10 cm)	dull yellowish brown clay, very firm, moderately developed coarse blocky structure;
9 in. (23 cm)	pale yellowish brown clay with bright brown mottles and small iron concretions, moderately developed coarse blocky structure;
on	weathered gravels and clay.

The Braeburn sandy loam is found alongside the Braeburn clay loam in the Moutere Valley. This soil is derivied from weathered Moutere Gravels, which have been water-sorted more than the Braeburn clay loam. This soil is less poorly drained but is still is moderately gleyed. Fertility is similar to the Braeburn clay loam.

A typical profile is:

9 in. (23 cm)	dark grey sandy loam, friable, strongly developed medium nutty and fine granular structure;
6 in. (15 cm)	dull yellowish grey silt loam with veins of topsoil, strongly developed coarse nutty structure;

8 in. (20 cm) greyish yellow silt loam with pale brown mottling, weakly developed medium blocky structure;

on clay.

The Tahunanui sand is formed on consolidated sand dunes of flat to rolling topography. Parent materials are a mixture of sediments, but north of Motueka are chiefly granite. Fertility is low.

A typical profile is:

10 in. (25 cm) dark gey fine sand, very friable, very weakly developed medium nutty structure;

6 in. (15 cm) pale greyish brown fine sand, weakly compacted, structureless;

on pale brown fine sand, loose, structureless.

The Tahunanui sand and gravel soil is located on the coast with low relief. Most of the soils are formed on sand of varying depths. The profile is very similar to that of the Tahunanui sand. These soils are prone to drought.

The Hau stony sandy loam is formed on the stony alluvium from greywacke, argillite, quartzite, limestone, granite, and basic igneous rocks. Stoniness is variable and fertility is low.

A typical profile is:

9 in. (23 cm) dark grey stony sandy loam, friable, moderately developed fine granular structure;

12 in. (30 cm) dull brown stony sandy loam, moderately developed fine nutty structure;

on stones and sand.

CHAPTER FOUR

Physical Properties of the Selected Soils

4.1 Introduction

Soil samples collected in the field were stored in chilly bins and transported to Massey University for analysis. During the time between when they arrived at Massey and were analysed they were stored in the department chiller, which is set at three degrees centigrade. Effort was taken to minimise the disturbance of the samples, and the samples were analysed as soon as possible (usually within days).

4.2 Soil Dry Bulk Density (ρ_b)

4.2.1 Introduction

Dry soil bulk density is the ratio of the mass of dried soil to the total volume of the soil (McLaren and Cameron, 1996). The general desired range for bulk densities is between 0.8 and 1.6 g cm^{-3}. Values that are below this range are prone to erosion (particularly by wind when cultivated). Values above this range often are compacted and limit water and root movement throughout the profile. Even one horizon of compacted soil may cause undesirable effects such as a perched water table.

Differences in soil texture also have an effect on soil dry bulk density. Sandy soils normally have a higher bulk density than a finer textured soil such as a silt loam soil (McLaren and Cameron, 1996). Organic matter also has a low bulk density- compared to the mineral fraction - thus causing topsoils to typically have a lower bulk density than the subsoils.

Compaction

Compacted soils have a significant effect on potential production under all land uses. Compaction occurs due to the repeated trafficking of machinery or stock, particularly over soil that is at or above its plastic limit. Correct management on susceptible soils is crucial to ensure that adverse effects are not exacerbated. These management practices are ensuring that:

- the soil is below the plasticity limit when machinery (especially heavy equipment such as full sprayers) is in use; *and*
- where required, an adequate irrigation programme is in place that recognises the variations in water holding capacities and soil hydraulic conductivity of the soil, and does not over water some areas.

The effects of compaction on the two major land uses in the study are quite different. Apples have a fibrous root system that extends to the width of the tree canopy. Therefore the compaction of the wheel ruts between the rows does not have a significant effect on plant growth. Kiwifruit on the other hand have a rooting pattern that spreads out laterally into the areas compacted by machinery, causing plant growth to be restricted. This issue has been previously mentioned with specific reference to the Motueka area by Haynes (1995).

4.2.2 Method

Dry soil bulk density was calculated for all the soils, with four replicate samples taken from each horizon. The samples were initially trimmed flush with the ends of the cores, and considerable care was taken not to remove soil from inside the core. Where some of the soil (up to 5%) was accidentally removed it was replaced by repacking it back into the core. The outsides of the cores were cleaned of excess soil. The samples were oven dried at 105°C for at least forty-eight hours, after which each sample was individually weighed along with the container they were in. The soil was then removed and the containers cleaned and returned to the oven for twenty-four hours. The containers were then weighed.

From this process the dry soil bulk density of the soil can be calculated by the use of equation 4.1.

$$\rho_b = \frac{\text{mass of dry soil}}{\text{total volume of soil}} \qquad \text{(equation 4.1)}$$

4.2.3 Results

A summary of the results is shown in table 4.1, with a full tabulation of results in appendix A2. The Riwaka, Sherry and Umukuri soils tend to increase in bulk density as depth increases. The Umukuri soil however is a lot more constant and does not vary substantially with depth as the bulk density of the topsoil is a lot greater than the other soils sampled.

The Riwaka, Sherry and Ferrer soils all have bulk densities of approximately 1.00 g/cm^3 in the top horizon, but vary considerably after this. The bulk density of the Riwaka soil quickly increases to 1.42 g/cm^3 and 1.59 g/cm^3 in the 12-17 cm and 40 cm plus horizons respectively. The Sherry soil increases gradually to a bulk density of 1.46 g/cm^3 below 47 cm. The Ferrer soil also increased gradually to a bulk density of 1.38 g/cm^3 below 47 cm. The Umukuri soil has a bulk density of 1.31 g/cm^3 in the topsoil, and reaches its lowest level at 40-45 cm with a bulk density of 1.25 g/cm^3. The highest bulk density in the Umukuri soil is in the bottom horizon (78-101 cm), with a value of 1.36 g/cm^3.

Riwaka		***Umukuri***		***Sherry***		***Ferrer***	
1-6 cm	0.98	**4-9 cm**	1.31	**1-6 cm**	1.03	**2-7 cm**	0.99
12-17 cm	1.42	**23-28**	1.34	**10-15 cm**	1.33	**15-20 cm**	1.13
40-45 cm	1.59	**40-45 cm**	1.25	**26-31 cm**	1.37	**35-40 cm**	1.30
75-80 cm	1.59	**65-70 cm**	1.27	**47-52 cm**	1.46	**60-65 cm**	1.38
		78-101 cm	1.36	**70-75 cm**	1.46	**100-105 cm**	1.38

Table 4.1. Bulk Density of the Sampled Soils (g/cm^3).

4.2.4 Discussion

All bulk density values fall within the desired range of 0.8-1.6 g/cm^3, however, the subsoil of the Riwaka and Ferrer soils are at the upper end of this desired level.

The reason for the elevated bulk density levels in the lower horizons of the Riwaka and Ferrer soils could possibly be due to the natural properties of the soils. These soils have similar texture (as shown in section 7.2 and summarised in appendix A7), but there was no granular data collected for laboratory analysis. The high bulk density in the Ferrer is somewhat more expected because of its poor drainage. Orchard activities may have contributed towards the observed bulk densities of the Riwaka soils. Machinery compaction may have increased the values in the subsoil, while frequent rotary hoeing would lower the bulk density in the topsoil. The high bulk density levels of the Riwaka soil do not seem to be having a significant effect on the current land use of the apple and pear orchard. Precautions though should be put into place to ensure that practices that may cause further compaction are kept to a minimum.

The results for the Umukuri and Sherry soils are typical of those expected for sandy soils, as they have reasonably high bulk densities.

4.3 Saturated Soil Hydraulic Conductivity (K_s)

4.3.1 Introduction

Saturated soil hydraulic conductivity (K_s) is a measure of the rate at which water passes through a soil in its saturated state. This is important, as it is a measure of water drainage through the soil profile. The desired range of K_s is between 0.36-360 mm hr^{-1} (McLaren and Cameron, 1996). Values below this range restrict plant growth to shallow rooting crops, as the ability to recharge plant available water to depth is insufficient. Values above this range have very low water holding potential and are only suitable to crops that are deep rooting. Generally sandy soils have the fastest K_s, then silts and clays respectively. This is due to the size of the pores that the water moves through. A pore with a size of 1 mm will drain at a rate 10,000 times faster than a pore with a size of 0.1 mm (McLaren and Cameron, 1996). Soil structure therefore also has an effect on the K_s of the soil. A well structured silt or clay soil will have a considerably faster K_s than its poorly structured equivalent.

K_s information should be considered when planning an irrigation program. Soils with a low K_s are severely restricted to the amount of water they can receive. Applying water at a rate in excess of the K_s will cause ponding and an inefficient irrigation system, which will also increase the chances of compaction as mentioned in section 4.2.2.

Classes for permeability are described by Griffiths (1982), and displayed in table 4.2.

Class	Saturated soil hydraulic conductivity (mm hr^{-1})
Very Rapid	>288
Rapid	144-288
Moderately Rapid	72-144
Moderate	18-72
Moderately Slow	4-18
Slow	1-4
Very Slow	>1

Table 4.2. Soil permeability classes (Griffiths, 1982).

4.3.2 Method

Three samples were collected at each soil horizon in cores that were approximately 150 mm high and a diameter of 73 mm. 100 mm of soil was collected in each core. In the laboratory, samples were trimmed with care not to cause smearing, which could lead to an impeding layer for water movement. Each sample was clamped in a retort stand with an empty container underneath. A mark was placed on the inside of the core to indicate five centimetres above the soil. Water was then added to each core up to this mark, and kept at this mark as it drained through the soil. Cores that showed obvious signs of water leaking between the metal core and the soil core (bypass flow) were discarded. Measurements were taken (generally every half an hour) of the water that passed through the core, until the amount of water exiting the core reached equilibrium. At this point the experiment was stopped.

Saturated soil hydraulic conductivity could then be calculated using equation 4.2.

$$K_s = \frac{\text{vol}\,H_2O\,(cm^3)}{\pi r^2\,(cm^2)} x \frac{1}{\text{Time(hour)}} = cm\,h^{-1} \qquad \text{(equation 4.2)}$$

where $\pi = 3.147$

4.3.3 Results

A summary of the results is shown in table 4.3, with full results in appendix A3.

Riwaka		*Umukuri*		*Sherry*		*Ferrer*	
1-11 cm	299	**4-14 cm**	120	**0-10 cm**	124	**2-12 cm**	370
12-22 cm	22	**23-33 cm**	84	**10-20 cm**	161	**15-25 cm**	41
40-50 cm	13	**40-50 cm**	390	**26-36 cm**	3816	**35-45 cm**	23
75-85 cm	3	**65-75 cm**	454	**47-57 cm**	70	**60-70 cm**	29
				70-80 cm	47	**100-110 cm**	4

Table 4.3. Saturated soil hydraulic conductivity of sampled soils (mm h^{-1}).

There is considerable variation both within each soil and between soils. Generally all the topsoils have moderate to very rapid permeability, with the Riwaka and Ferrer soils showing values of 299 and 370 mm h^{-1} respectively. The K_s of the subsoil in these soils though are considerably lower, and decreases with depth. Both these soils enter the slow permeability class in their lowest horizons, with values of 3 and 4 mm h^{-1} respectively. The Umukuri and Sherry soils have excessively high K_s with values up to 454 mm h^{-1} at 65-75 cm for the Umukuri soil, and values up to 3816 mm h^{-1} in the coarse granitic sand at depth 26-36 cm of the Sherry soil. The horizons with the lowest K_s in these soils are still classed as moderate to moderately rapid, with the Umukuri soil having a K_s of 84 mm h^{-1} in the 23-33 cm horizon, and the Sherry soil with 47 mm h^{-1} at 70-80 cm. There is no apparent trend with depth in the permeability of the Umukuri and Sherry soils.

4.3.4 Discussion

Saturated soil hydraulic conductivity appears to be related to the texture of the soil. The sandier Sherry and Umukuri soils generally have higher rates of flow throughout the profile, while the siltier Riwaka and Ferrer soils tend to have a much slower K_s.

The moderate K_s in the silty Riwaka and Ferrer topsoils is probably due to macropores produced by worms, plant roots, and also structural development. The wormholes in the topsoil are likely to remain intact for a considerable time, due to the silty nature of the soil. These influences decrease with depth and the K_s values (which are classified as slow) in the lowest horizons of the Riwaka and Ferrer soils are of concern. The Ferrer soil has a rising or less likely a perched water table during periods of prolonged wetness. The lack of mottling suggests that a water table is not present for any length of time in the Riwaka soil, however the high bulk density and low K_s point to the need for careful application of irrigation water, and drains as a safety measure. Significant areas with problems from over irrigation (such as ponding and deep wheel ruts) were observed on the Riwaka soil during fieldwork.

The Umukuri and Sherry soils both have reasonably free draining profiles, which should allow rapid movement of water throughout the profile. Both profiles are very young and composed of layered alluvium of contrasting texture. It is thus not surprising that K_s and the bulk density should be so variable. The rapid loss of irrigation water via lateral flow in the coarser layers of these soils is likely to render irrigation management difficult.

4.4 Soil Water Retention

4.4.1 Introduction

Soil water retention is the ability of a soil to retain water in its matrix that plant roots can access. Texture is the biggest variable that has an effect on the amount of water stored (figure 4.1). Sands typically have a lower water storage capacity than silts and clays as they have less surface area relative to the volume they occupy. The gaps in between each sand particle also are a lot larger, causing the water to be lost by gravitational forces more readily.

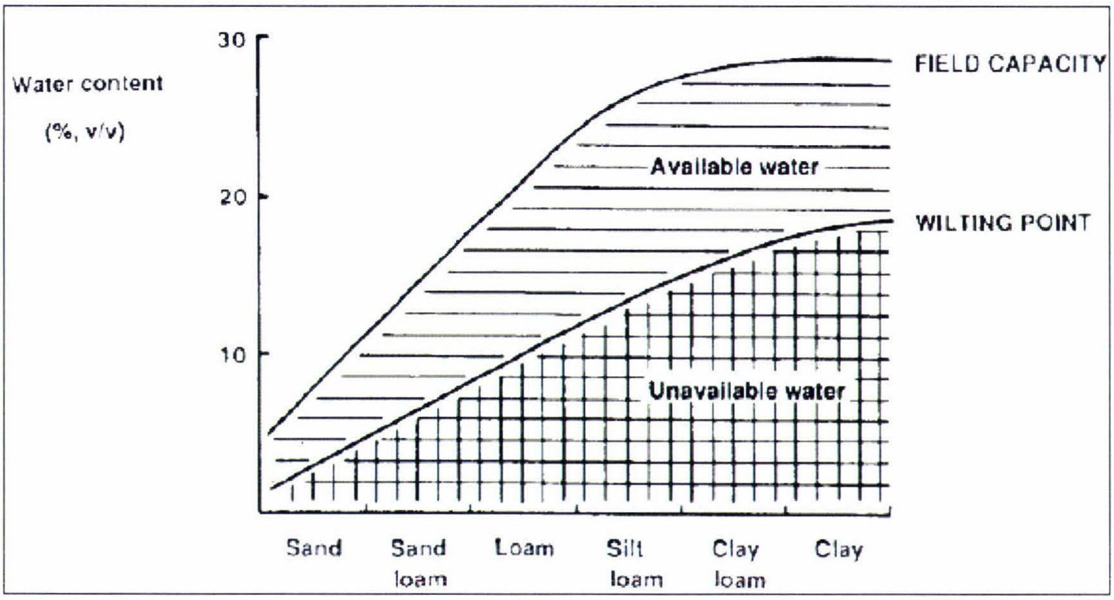


Figure 4.1. Typical relationship between soil texture and soil water content (McLaren and Cameron, 1996).

There are three key points of water retention that are used to assess the plants ability to use water (figure 4.2). The first is at 0.1 bar (-10 kPa), where the soil is said to be at 'field capacity'. This is determined as the moisture content of the soil after the soil has been saturated with water, and left to stand for two days to a point where rapid drainage has ceased, and the soil water content is relatively constant. The second point is known as 'stress point', and is measured at 1 bar (-100 kPa). At this point plants have used all the easily extracted water, and as the soil dries further must work increasingly harder to extract water for survival. Stress point approximates the point of cessation or significant slowing of growth. The final and third level is described as 'permanent wilting point', and is measured at 15 bar (-1500 kPa). At this point plants are no longer able to extract water from the soil, and are in a state of permanent wilt. The zone from field capacity to stress point is called 'readily available water' (RAW), as this water is readily available for plants to utilise. Total available water (TAW) is taken from field capacity to permanent wilting point.

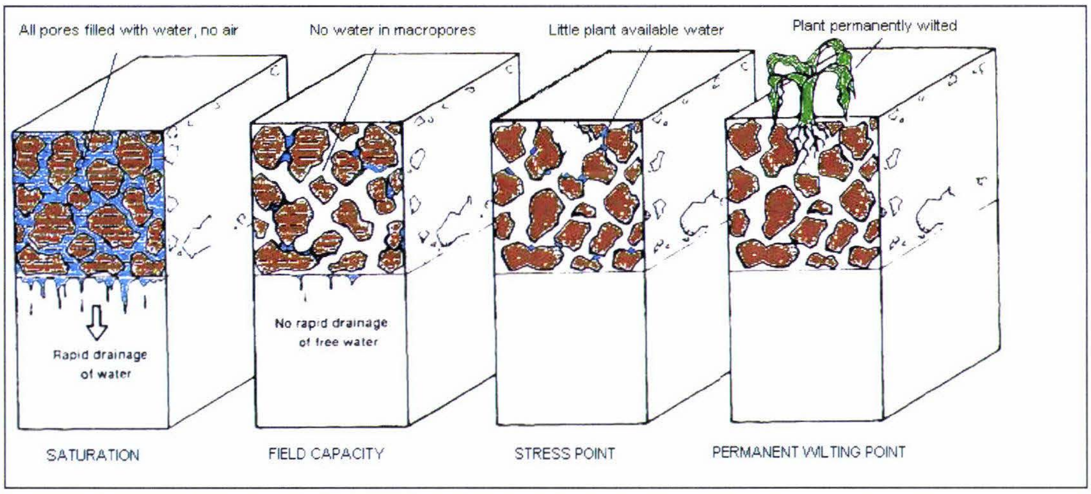


Figure 4.2. Representation of soil water contents at Saturation, Field Capacity, Stress Point and Permanent Wilting Point (*adapted from* McLaren and Cameron, 1996).

A classification table for the profile readily available water is displayed in table 4.4.

PRAW (mm) in top 1m	Class
>100	Very high
67-100	High
50-67	Moderately high
33-50	Moderate
17-33	Low
<17	Very low

Table 4.4. Classification of profile readily available water (*adapted from* Webb and Wilson, 1995).

4.4.2 Method

Four samples collected from each horizon in small cores approximately 15 mm high and with a diameter of 50 mm. The samples were cleaned of excess soil and placed on ceramic pressure plates and submerged in water. The samples were left to soak for twenty-four hours, which ensured that the soil was at a saturated state. Two of the core samples were placed on the 0.1 bar and 1 bar plates, and one sample of loose soil was placed inside rubber rings and placed on the 15 bar plate. This was done as at the lower pressures, soil structure has an effect on the water holding capacity, whereas at the higher pressure, water holding capacity is almost entirely dependant on soil texture. The 0.1 bar pressure plate was placed in a sealed plastic bag, which was connected to a bubble tower. The other two pressure plates were placed in pressure chambers and placed under 1 bar and 15 bar pressure.

The samples were left until there was no further water being lost from the pressure chambers, and were then removed and weighed. The bubble tower samples were typically removed after four days, while both the other sets of samples were kept under pressure for at least two weeks. When the samples were removed they were placed onto a small container and weighed wet. They were then placed in an oven set at 105°C for at least forty-eight hours, and then reweighed. The soil was then removed from the cores and the containers were cleaned, oven dried and reweighed. From this process, the amount of water in each soil was calculated using equations 4.3 and 4.4.

$$\text{Volumetric Water} = \left(\frac{wet\ weight - dry\ weight}{dry\ weight - container\ weight} \right) x\ \rho_b \qquad \text{(equation 4.3)}$$

$$\begin{array}{l}\text{Amount of water}\\ \text{in horizon or layer}\end{array} = \left(\frac{Volumetric\ water\ in\ layer\ (\%)}{100} \right) x\ depth\ of\ layer\ (mm) \qquad \text{(equation 4.4)}$$

4.4.3 Results

A summary of the results is shown in figure 4.5, with full results shown in appendix A4. There is considerable variation between and within soils, with readily available values for the upper one metre of the profile ranging from 59 mm in the Riwaka soil, up to 134 mm in the Ferrer soil. The distribution of water in the soil profile is reasonably even, with the exception of the Riwaka soil that has substantially more water in the upper part of the profile. The difference between the readily available and total available water contents in all soils ranges between approximately 20 and 40 mm.

The Riwaka soil has a high amount of plant readily available water in the top 12 cm, with 29.3 mm (24.4%) present in this small horizon. Below this the amount of water decreases dramatically, with a total of 29.9 mm in the remaining 88 cm of the profile.

While the total plant available water is higher with 97.5 mm, it is still significantly lower than the other soils sampled.

The Umukuri and Sherry soils, which are both sandy soils, have relatively high levels of readily available water with 114 and 84 mm respectively. The distribution of water in these profiles is fairly uniform throughout the profile. The coarse granitic sand horizon in the Sherry soil is quite obvious, with a readily available water content of only 4.3 mm.

The Ferrer soil has by far the greatest amount of plant readily available water of the sampled soils, with 133.9 mm in the top 100 cm, or 146.8 mm in the top 120 cm. Total available plant water is also the highest with 169.7 mm in the upper 120 cm of the profile.

Riwaka	*Readily*	*Total*	*Umukuri*	*Readily*	*Total*	*Sherry*	*Readily*	*Total*	*Ferrer*	*Readily*	*Total*
0-12 cm	29.3	48.1	**0-23 cm**	26.2	33.8	**0-10 cm**	17.8	21.5	**0-15 cm**	17.1	22.0
12-40 cm	8.7	14.3	**23-40 cm**	19.9	22.8	**10-26 cm**	17.6	19.6	**15-35 cm**	23.5	26.8
40-75 cm	14.5	22.6	**40-65 cm**	34.9	42.9	**26-47 cm**	4.3	5.5	**35-60 cm**	34.9	42.1
75-100 cm	6.7	12.6	**65-78 cm**	19.0	20.6	**47-70 cm**	18.6	26.9	**60-100 cm**	58.6	63.5
			78-100 cm	14.2	16.8	**70-100 cm**	25.3	33.5	**100-120 cm**	12.9	15.3
Total to 1m	59	98	**Total to 1m**	114	136	**Total to 1m**	84	107	**Total to 1m**	134	155

Table 4.5. Readily and total available water in sampled soils (mm).

4.4.4 Discussion

The readily available water in the Umukuri, Sherry and Ferrer soils follow the expected trend, however, the Riwaka soil is well below what was expected. Typically, as discussed in section 4.4.1, silty soils typically have higher amounts of available and total water than sandy soils (Sherry and Umukuri). The reason for the lower moisture holding capacity in the Riwaka soil is uncertain, but it could be due to high bulk densities, or perhaps due to the exceptionally slow saturated soil hydraulic conductivity, which did not allow the samples to reach field capacity before being placed into the pressure plates during sampling. The amount of readily available water in the Riwaka soil though is still classified as moderately high.

CHAPTER FIVE

Chemical Properties of the Selected Soils

5.1 Introduction

Soil samples collected in the field were transported to Massey University and analysed by the Fertilizer and Lime Research Centre (full results in appendix A5). Due to finical constraints only one sample from each horizon was texted. Bulk samples were collected from each soil horizon and stored in plastic bags. Samples consisted of a section of the entire horizon. Ten core samples to a depth of 10 cm taken from the surrounding land within 25m of the pit were also collected.

Chemical properties of the soil are very important because nutrients are in essence the food plants use for growth and production. Establishing a sound understanding of the chemical properties present can therefore give the land manager a better understanding of areas that might need attention. This will usually mean the addition of fertilisers to correct any deficiencies that each soil may possess, and provide available nutrients for the growing crop.

Ranges for chemical properties are given by Blackmore *et al.* (1987) (Table 5.1) to facilitate description of the levels of each chemical parameter.

RATINGS FOR CHEMICAL PROPERTIES

The following ratings of chemical properties are used by NZ Soil Bureau for New Zealand soils.

Rating	pH (1:2.5 soil:water) (1A)[1]	Organic matter: Organic C (%) (3A or B)	Organic matter: Total N (%) (4A or B)	C/N	Phosphorus: Truog (μg/g) (5A)	Phosphorus: Olsen (μg/g) (5B)	Phosphorus: 0.5 M H_2SO_4 (mg/100 g) (5D)	Phosphorus: Inorganic (mg/100 g)	Phosphorus: Organic (mg/100 g) (5E)	Phosphorus: Total (mg/100 g) (5F)	P retn. (%) (5G)
Very high	> 9.0 (extremely alkaline) 8.4–9.0 (strongly alkaline) 7.6–8.3 (moderately alkaline)	> 20	> 1.0	> 24	> 50	> 50	> 40	> 50	> 70	> 120	90–100
High	7.1–7.5 (slightly alkaline) 6.6–7.0 (near neutral)	10–20	0.6–1.0	16–24	30–50	30–50	20–40	30–50	50–70	80–120	60–90
Medium	6.0–6.5 (slightly acid) 5.3–5.9 (moderately acid)	4–10	0.3–0.6	12–16	20–30	20–30	10–20	20–30	20–50	40–80	30–60
Low	4.5–5.2 (strongly acid)	2–4	0.1–0.3	10–12	10–20	10–20	5–10	10–20	10–20	20–40	10–30
Very low	< 4.5 (extremely acid)	< 2	< 0.1	< 10	< 10	< 10	< 5	< 10	< 10	< 20	0–10

Rating	Cation exchange properties (NH_4OAc, pH7): CEC (me./100 g) (6A4)	Σ Bases (me./100 g) (6A3)	BS (%) (6A5)	Ca (me./100 g) (6A2)	Mg (me./100 g) (6A2)	K (me./100 g) (6A2)	Na (me./100 g) (6A2)	KCl-extr. Al (me./100 g) (6B1)	Exchange Acidity (pH 8.2) (me./100 g) (6C1)	Reserve K_c (me./100 g) (7A)	Reserve Mg (me./100 g) (7B)
Very high	> 40	> 25	80–100	> 20	> 7	> 1.2	> 2	> 5	> 60	> 0.5	> 30
High	25–40	15–25	60–80	10–20	3–7	0.8–1.2	0.7–2	2–5	30–60	0.35–0.5	15–30
Medium	12–25	7–15	40–60	5–10	1–3	0.5–0.8	0.3–0.7	0.5–2.0	15–30	0.20–0.35	7–15
Low	6–12	3–7	20–40	2–5	0.5–1	0.3–0.5	0.1–0.3	0.1–0.5	5–15	0.10–0.20	3–7
Very low	< 6	< 3	< 20	< 2	< 0.5	< 0.3	< 0.1	< 0.1	< 5	< 0.10	< 3

Rating	Acid oxalate-extractable Al (%) (8A)	Acid oxalate-extractable Fe (%) (8A)	Acid oxalate-extractable Si (%) (8A)	Pyrophosphate-extractable Al (%) (8B)	Pyrophosphate-extractable Fe (%) (8B)	Dithionate-citrate-extractable Al (%) (8C)	Dithionate-citrate-extractable Fe (%) (8C)	Phosphate-extractable sulphur or sulphate (μg S/g) (11A or B)	Soluble salts: Conductivity[2] (millimho/cm) (9A)	Soluble salts: % salts (9A)
Very high	> 3.0	> 2.0		> 2.0	> 1.2	> 2.0	> 4.0	> 150	> 2	> 0.7
High	1.0–3.0	1.0–2.0	> 0.5	0.8–2.0	0.6–1.2	1.0–2.0	2.0–4.0	50–150	0.8–2	0.3–0.7
Medium	0.5–1.0	0.5–1.0	0.15–0.5	0.4–0.8	0.3–0.6	0.5–1.0	1.0–2.0	15–50	0.4–0.8	0.15–0.3
Low	0.2–0.5	0.2–0.5	0.05–0.15	0.1–0.4	0.1–0.3	0.2–0.5	0.5–1.0	5–15	0.15–0.4	0.05–0.15
Very low	< 0.2	< 0.2	< 0.05	< 0.1	< 0.1	< 0.2	< 0.5	< 5	< 0.15	< 0.05

[1] Numbers in brackets refer to the number of the analytical method in NZ Soil Bureau Scientific Report 80.
[2] Conductivity of the 1:5 extract at 25°C

Table 5.1. Ratings for chemical properties of New Zealand Soils (Blackmore *et al.*, 1982).

5.2 Soil Acidity

5.2.1 Introduction

Soil acidity or alkalinity is a measure of the relative concentrations of hydrogen (H^-) and hydroxyl (OH^-) ions in a soil solution. Acidity or alkalinity of the soil is expressed numerically on a scale, the pH scale. This scale ranges in logarithmic steps from 0 to 14, with 0 being extremely acid (only H^- ions), and 14 being extremely alkaline (only OH^- ions). The value of 7 is therefore the midpoint, where the pH is said to be neutral.

At this point concentrations of H^- and OH^- ions are equal, cancelling the effect of each other.

Soil pH is influenced by the cation exchange capacity (discussed in section 5.3) of the soil (Cornforth, 1998). When the cation exchange capacity is filled with basic cations such as potassium, calcium, magnesium and sodium the soil will have a base saturation of near 100%, and will also have a pH that is approximately 7. So when soil loses these cations they are replaced by H^- ions, and consequently pH is reduced. In their natural state soils tend to become acidic by:

- the growth of vegetation;
- decomposition of organic matter;
- biological nitrogen fixation;
- nitrification; *and*
- leaching (Cornforth, 1998).

Cultural processes that can increase the rate of acidification are:

- increased plant growth rates by the intensification of agriculture;
- the introduction of nitrifying legumes;
- the loss of cations in produce exported off the property; *and*
- addition of fertilizers such as urea and elemental sulphur.

Soils tend usually to be acidic due to the processes mentioned above. However, soils can be basic (pH greater than 7) if there is a significant amount of limestone in the soil, or if the soil has a salinity problem. The over application of certain fertilisers can also cause the soil pH to rise above 7.

Soil pH has an effect on the availability of individual nutrients (figure 5.1). Calcium, magnesium, nitrogen and sulphur availability increase with pH, the first two more markedly than the other two. Phosphorus availability also increases with pH to a value of 6.5, where it then decreases again. Micronutrients generally increase in availability as pH decreases, with the exception of molybdenum, which increases in availability with pH. At lower pH values these micronutrients can often occur at levels that are toxic to plants.

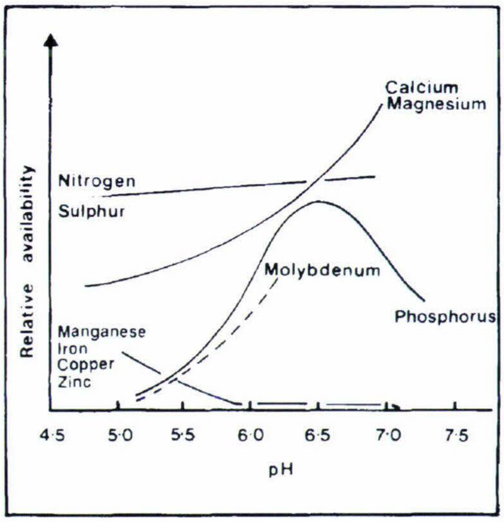


Figure 5.1. Relative nutrient availability and pH relationships (McLaren and Cameron, 1996).

Each plant has differing preferred pH levels at which they survive and grow. Most plants produce their optimum yields in a slightly acidic soil (figure 5.1).

Crop	*Optimum pH range*	*Other features*
Apples/pears	5.8—6.8	
Stone fruit	6.0-6.7	In top 40 cm
Blackcurrants	>5.8	
Blueberries	4.0-5.0	
Boysenberries	5.8-6.5	
Raspberries	5.8-6.5	
Strawberries	5.3-6.5	
Kiwifruit	4.5-6.8	Texturally dependant
Grapes	5.8-6.8	
Citrus	5.5-6.5	
Feijoas	5.8-6.8	
Pasture - ryegrass	5.5-6.5	

Table 5.2. Optimum pH levels for crops (Clarke et al., 1986).

5.2.2 Results

All soils fall within the medium rating of soil pH, either being slightly or moderately acidic. Soil pH values vary considerably between soils, but vary little between horizons within each soil (Table 5.3). The Riwaka and Umukuri soils have pH values between the range of 6.1 and 6.5, while the Sherry and Ferrer soils have pH values of 5.5 in the topsoil, which increased to 5.9 and 5.7 respectively in the lowest horizon.

Riwaka		*Umukuri*		*Sherry*		*Ferrer*	
0-10 cm comp	6.3	**0-10 cm comp**	6.4	**0-10 cm comp**	5.5	**0-10 cm comp**	5.4
0-10 cm pit	6.4	**0-10 cm pit**	6.5	**0-10 cm pit**	5.4	**0-10 cm pit**	5.5
10-38 cm	6.4	**10-28 cm**	6.5	**10-26 cm**	5.4	**10-32 cm**	5.4
38-70 cm	6.3	**28-36 cm**	6.3	**26-47 cm**	5.6	**32-51 cm**	5.3
70-110 cm	6.4	**36-61 cm**	6.3	**47-70 cm**	5.7	**51-93 cm**	5.5
		61-78 cm	6.1	**70-92 cm**	5.7	**93-120 cm**	5.7
		78-101 cm	6.4	**92-100 cm**	5.9		

Table 5.3. pH values of sampled soils.

5.2.3 Discussion

The levels of pH in the sampled soils are desirable. The soil pH may have been affected by land use management practices. The soils that are, or have recently been in horticulture (Riwaka and Umukuri) have the higher pH range, while the soils is pasture have the lower pH range. More attention may have therefore been placed on soil pH in the horticultural soils, and practices to increase the pH in the soil (e.g. the addition of lime) may have been carried out.

5.3 Cation Exchange Capacity

5.3.1 Introduction

Cation exchange capacity (CEC) is the number of exchangeable cations that can be held on negatively charged surfaces in a soil. In essence it is the number of negative charges that a soil possesses. The higher the CEC the greater the amount of cations that can be held in the soil, and can then be used by plants for growth. CEC is dependant on the texture and type of material that makes up the soil. Humus and certain types of clays have many negative charges, and therefore have a high CEC. Coarser textures such as sand and even silt will have a lot lower CEC, because these soil particles have significantly less surface area and hence fewer cation exchange sites. The types of clays that have a high CEC are vermiculite, smectite and allophane. Humus has a high CEC, therefore topsoils tend to always have a higher CEC than subsoils.

5.3.2 Results

From the sampled soils CEC varies considerably from soil to soil (Table 5.4). The Riwaka and Ferrer soils have higher CEC values, ranging from 13 to 23 me/100g, than the Sherry and Umukuri soils, which range from 3 to 17 me/100g. The soils also follow the trend of having high values in the topsoil, which then decrease in the lower horizons. The Umukuri and Sherry soils displayed this trend more obviously than the Riwaka and Ferrer soils. The CEC in the subsoils of the Umukuri and Sherry soils are very low, often in single figures and with both reaching 3 me/100g in the lowest horizon.

Riwaka		*Umukuri*		*Sherry*		*Ferrer*	
0-10 cm comp	22	**0-10 cm comp**	15	**0-10 cm comp**	15	**0-10 cm comp**	19
0-10 cm pit	23	**0-10 cm pit**	17	**0-10 cm pit**	12	**0-10 cm pit**	22
10-38 cm	17	**10-28 cm**	12	**10-26 cm**	10	**10-32 cm**	18
38-70 cm	16	**28-36 cm**	13	**26-47 cm**	4	**32-51 cm**	13
70-110 cm	15	**36-61 cm**	7	**47-70 cm**	2	**51-93 cm**	14
		61-78 cm	6	**70-92 cm**	4	**93-120 cm**	16
		78-101 cm	3	**92-100 cm**	3		

Table 5.4. CEC of sampled soils (me/100g).

5.3.3 Discussion

The variations appear to follow differences in texture. The silty Riwaka and Ferrer soils have higher values than the sandy Umukuri and Sherry soils, which is to be expected. The trend of decreasing CEC down the profile is also expected. The Riwaka and Ferrer soils have medium levels (12-25 me/100g) of CEC in the top 60 cm. The Sherry and Umukuri soils have CEC values that are rated as low in the upper 60 cm of the profile. This is a disadvantage, especially with the Sherry and Umukuri soils, as the number of cations that these soils are able to hold is low.

5.4 Base Saturation

5.4.1 Introduction

Base saturation is the proportion of the negatively charged sites in the soil that are occupied by exchangeable bases (all the exchangeable cations except for H^+ and Al^{3+}). Fundamentally it is the level to which the nutrients (cations) have filled up the cation exchange sites. A low base saturation indicates that there is still room for additional cations in the soil. Base saturation is also an indicator of pH. If a soil has a low base saturation then a high proportion of the cation exchange sites will be occupied by H^+ ions, thus causing the pH to be low.

Base saturation in association with pH can give a rough guide to the buffering capacity of the soil. Buffering capacity is defined as the ability of the soil to change pH when circumstances alter (McLaren and Cameron, 1996). A soil with a pH near neutral and a low base saturation would indicate that the soil has a high buffering capacity.

5.4.2 Results

Most of the sampled soils have medium levels of base saturation that do not exhibit substantial variation throughout the profile, especially the Riwaka and Umukuri soils (Table 5.5). However, the Sherry soils are significantly lower with very low values that average 35% in the topsoil, but decrease to 6% in the subsoil. The Ferrer soil also has moderately low values ranging between an averaged 53% in the top 10 cm down to 25% in the subsoil (32-51 cm). The Ferrer soil does not display any obvious trends with base saturation and depth, unlike the Sherry soil.

Riwaka		*Umukuri*		*Sherry*		*Ferrer*	
0-10 cm comp	67	**0-10 cm comp**	75	**0-10 cm comp**	32	**0-10 cm comp**	55
0-10 cm pit	73	**0-10 cm pit**	77	**0-10 cm pit**	37	**0-10 cm pit**	49
10-38 cm	62	**10-28 cm**	69	**10-26 cm**	24	**10-32 cm**	36
38-70 cm	54	**28-36 cm**	61	**26-47 cm**	13	**32-51 cm**	25
70-110 cm	58	**36-61 cm**	49	**47-70 cm**	21	**51-93 cm**	35
		61-78 cm	55	**70-92 cm**	6	**93-120 cm**	47
		78-101 cm	61	**92-100 cm**	6		

Table 5.5. Base saturation of sampled soils (%).

5.4.3 Discussion

The Riwaka and Umukuri soils both have high base saturation (between 60-80% in the top 60 cm). The Ferrer and Sherry soils both have low base saturation (20-40%) in the upper 60 cm. These differing levels of base saturation in these soils may be a result of land management practices (particularly fertilizer and lime application) of the present land use at the sampled sites.

An indication to the buffering capacity of the soils can also be obtained with the correlation of the base saturation to the pH of the soils. The pH of the Sherry and Ferrer soils is lower than the Riwaka and Umukuri soils (section 5.5.2). This combined with the low base saturation of the Sherry and Ferrer soils, and higher values in the Riwaka and Umukuri soils, indicates that all the soils sampled have a similar buffering capacity.

5.5 Exchangeable Cations – Potassium, Calcium, Magnesium and Sodium

5.5.1 Introduction

Potassium

Potassium (K) is a vital element in the growth and production of vegetation. Its role in the growth of plants involves controlling the rate of carbon dioxide assimilation, assisting in balancing the charge of anions, and the initialising enzyme processes (McLaren and Cameron, 1996). More specifically for horticultural operations it controls the sugars in fruits. K deficiencies in vegetation can be seen by the browning of leaf edges. It is suggested that responses to K fertiliser is expected on soils that have a value of less that 0.28 me/100g, whereas soils with values of greater than 0.56 me/100g a response to fertiliser is very unlikely (McLaren and Cameron, 1996). The normal range of soil potassium that crops require does not vary substantially from crop to crop (Table 5.6).

Crop	*Normal Potassium range*
Apples/pears	0.5-1.0
Stone fruit	0.5-1.0
Blackcurrants	0.6-1.2
Raspberries	0.5-0.8
Strawberries	0.5-0.8
Kiwifruit	0.6-1.2
Grapes	0.4-0.8
Citrus	0.5-0.8
Feijoas	0.5-1.0

Table 5.6. Normal soil test potassium ranges (me/100g) for selected crops (Hill Laboratories, 2002).

Calcium

The role of calcium (Ca) in the growth of plants is crucial. It is vital for the growth of root tips and also is a significant feature in the production of cell walls. In fruit crops a deficiency in calcium leads to problems such as bitter pit in apples. It is thought that good subsoil levels of Ca will assist in reduction of problems such as bitter pit (Clark, 1986). Significant quantities of Ca in the soil also encourages activity of soil organisms, which in turn leads to increased aeration and a stable soil structure (McLaren and Cameron, 1996).

Normal ranges for calcium in soils are between 5 and 12 me/100g (Hill Laboratories, 2002). Parent material of a soil is the main factor for determining the Ca levels in the soil. Soils made up of limestone and other rocks with a high concentration of Ca will normally have adequate supplies of Ca. Soil pH and exchangeable calcium levels are usually closely related (figure 5.1). The more acidic the soil is (the lower the pH), the more likely the amount of Ca in the soil will be lower.

Magnesium

Magnesium (Mg) is a vital part of the photosynthesis process, as it is the central ion in chlorophyll. If this element is deficient then the leaves of plants tend to lose the green colour between their veins. Other effects on plants are not significant. Effects of Mg deficient soils on animals, however, can be dramatic, especially on lactating dairy cattle where a lack of Mg can cause hypomagnesaemia (grass staggers).

All crops investigated generally have a similar range at which soil Mg is required to achieve optimum growth. This is a range of between 1-3 me/100g (Hill Laboratories, 2002).

Sodium

Sodium (Na) is more important for the growth of animals than the growth of crops. Deficiencies of Na in the soil have not been recognised in the growth of crops, but it has been proven that the addition of Na can increase the yields of some crops such as beets, spinach and mangolds (McLaren and Cameron, 1996). Na is also thought to be able to substitute for some of the processes that potassium carries out.

Sodium levels in soils do not have to be high and most soils contain a sufficient amount of Na for crop production. Excessive levels of Na in the soil, however, can lead to salinity problems, but this is not really an issue in New Zealand apart from areas of low rainfall in Central Otago and some soils within close proximity to the coast. It is considered that soil levels of 0-0.5 me/100g are the normal range for New Zealand soils (Hill Laboratories, 2002).

5.5.2 Results

The full results of the tested exchangeable cations are displayed in table 5.7, with summarising graphs shown in figures 5.2-5.5. Generally there is a trend of decreasing concentrations of cations with depth. The Riwaka soil also typically has the highest values with the Umukuri and Ferrer soils second, and the Sherry soils predominantly have the lowest.

Riwaka	K	Ca	Mg	Na	Umukuri	K	Ca	Mg	Na	Sherry	K	Ca	Mg	Na	Ferrer	K	Ca	Mg	Na
0-10 cm comp	0.39	12.4	2.06	0.07	**0-10 cm comp**	0.67	7.7	2.82	0.03	**0-10 cm comp**	0.15	3.8	0.61	0.08	**0-10 cm comp**	0.61	8.6	1.38	0.13
0-10 cm pit	0.54	14.3	2.29	0.06	**0-10 cm pit**	0.82	8.8	3.21	0.02	**0-10 cm pit**	0.12	3.5	0.68	0.06	**0-10 cm pit**	0.31	8.4	1.74	0.16
10-38 cm	0.23	8.7	1.36	0.07	**10-28 cm**	0.49	5.3	2.48	0.02	**10-26 cm**	0.06	2.0	0.26	0.06	**10-32 cm**	0.10	5.2	0.83	0.07
38-70 cm	0.04	6.3	2.52	0.05	**28-36 cm**	0.30	4.7	2.69	0.04	**26-47 cm**	0.02	0.4	0.07	0.02	**32-51 cm**	0.15	2.8	0.35	0.04
70-110 cm	0.06	4.8	3.61	0.07	**36-61 cm**	0.12	2.3	1.20	0.01	**47-70 cm**	0.02	0.2	0.05	0.02	**51-93 cm**	0.05	3.9	0.77	0.06
					61-78 cm	0.03	2.5	0.45	0.02	**70-92 cm**	0.01	0.2	0.02	0.04	**93-120 cm**	0.03	4.8	2.69	0.13
					78-101 cm	0.08	1.5	0.33	0.04	**92-100 cm**	0.01	0.1	0.01	0.03					

Table 5.7. Exchangeable cations of sampled soils (me/100g).

The values of exchangeable potassium in the sampled soil generally decrease with depth, and are normally much higher in the topsoils (figure 5.2). The Umukuri soil has the highest values with 0.82 me/100g recorded from the pit sample. All the soils values decrease to below 0.1 me/100g in the lowest two horizons. The Sherry soil has particularly low values with values ranging from 0.15 me/100g of exchangeable K in the topsoil, down to only slightly detectable amounts of exchangeable K in the subsoil.

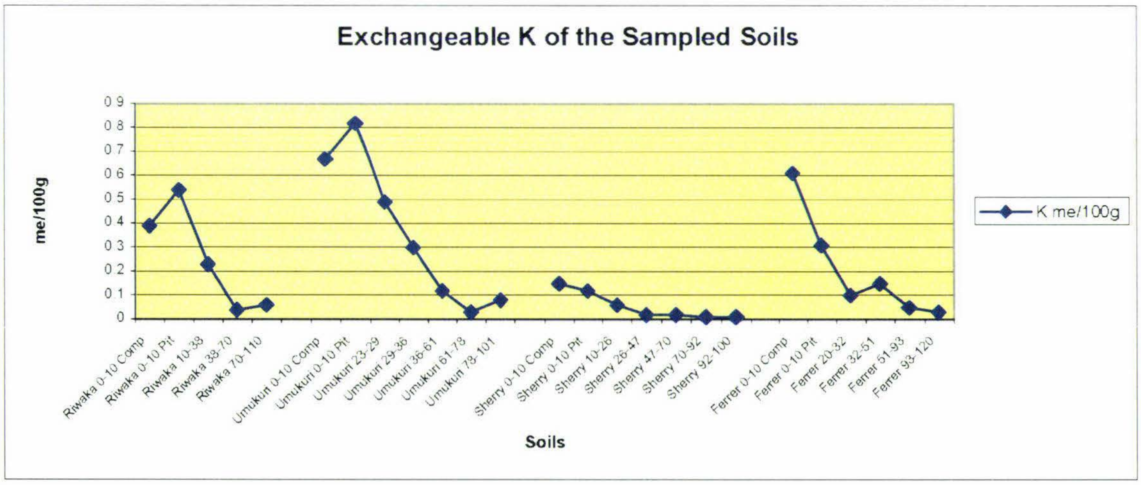


Figure 5.2. Exchangeable K of sampled soils (me/100g).

Levels of exchangeable calcium are highest in the Riwaka soil with values reaching 14.3 me/100g in the 0-10 cm pit sample. The Umukuri and Ferrer soils have very similar exchangeable Ca, ranging from approximately 9 me/100g to just below 2 me/100g (figure 5.3). The Sherry soil has the lowest amount of exchangeable calcium in the sampled soil, and has values that range from 3.8 me/100g in the topsoil down to 0.1 me/100g in the lower subsoil.

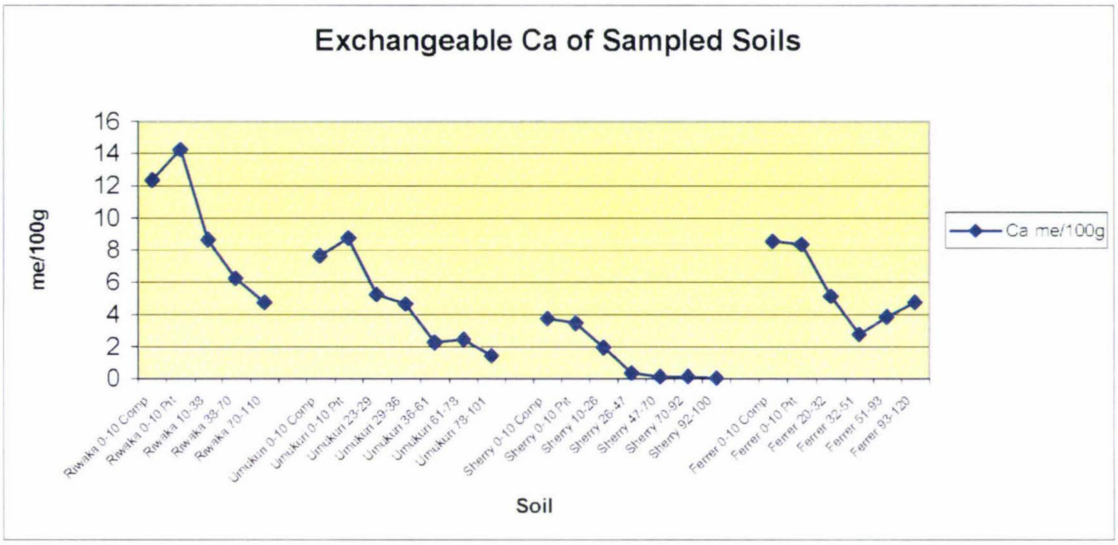


Figure 5.3. Exchangeable Ca of sampled soils (me/100g).

The Umukuri and Sherry soils show decreasing amounts of exchangeable Mg with depth, while the Riwaka and Ferrer soils both tend to initially to decrease, but values increase in the lower horizons (figure 5.4). Often these increases in the lower horizons resulted in values, which were higher than in the topsoil. The Riwaka soil had the highest amount of exchangeable Mg, which peaked at 3.61 me/100g in the lowest horizon. The Sherry soil had the lowest values, which ranged from an average of 0.65 me/100g in the top 10 cm, down to values as low as 0.1 me/100g in the lowest horizon.

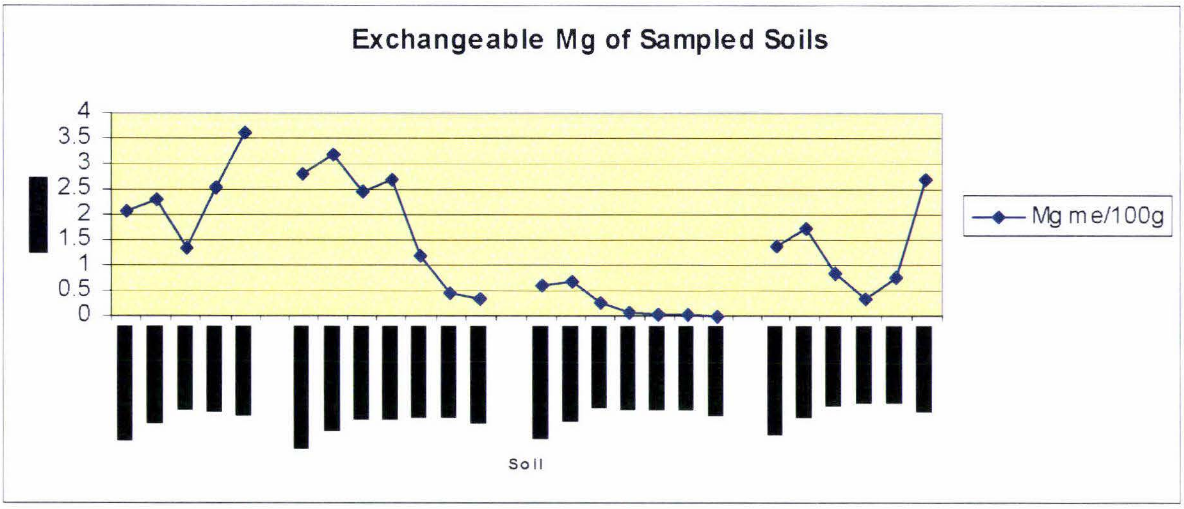


Figure 5.4. Exchangeable Mg of sampled soils (me/100g).

Levels of exchangeable sodium in the soils tested do not seem to follow trends similar to the other cations. Ferrer soils contain the highest levels of exchangeable Na with 0.16 me/100g in the 0-10 cm pit sample (figure 5.5). The Ferrer soil decreases to a value of 0.04 me/100g in the 32-51 cm horizon, where it increases again. Umukuri soils have the lowest values, which range between 0.01 and 0.04 me/100g. The Riwaka soil varies little and averages 0.06 me/100g, and the Sherry soil ranges between 0.03 and 0.08 me/100g.

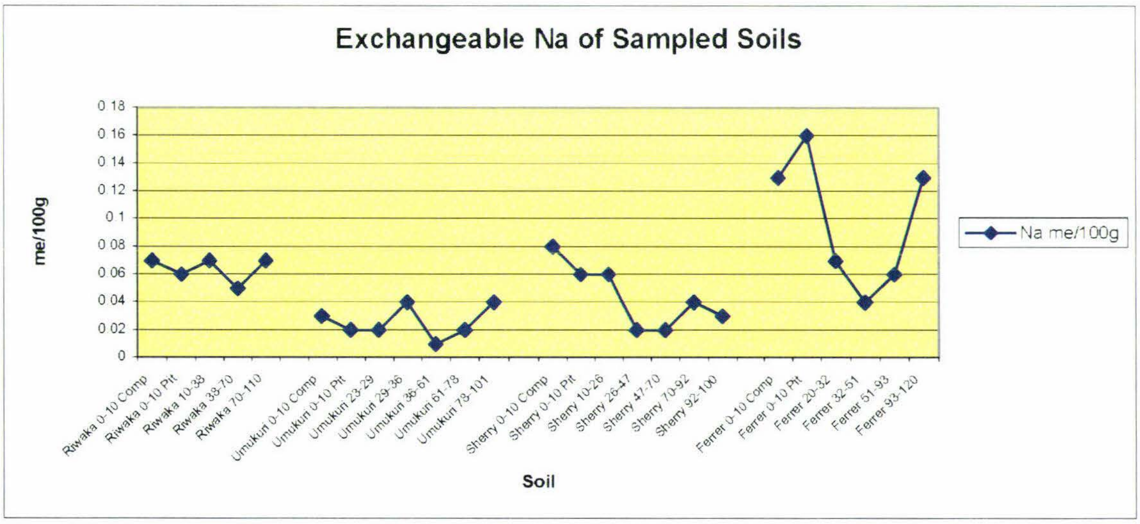


Figure 5.5. Exchangeable Na of sampled soils (me/100g).

5.5.3 Discussion

The generally higher values of each exchangeable cation in the Riwaka and Ferrer soils are likely to be due to the siltier nature of these soils, compared to the sandier Umukuri and Sherry soils, and is to be expected. The common trend to decreasing values with depth also is expected due to lower amounts of organic matter and weathered material at depth.

Differences in the 0-10 cm samples taken from the pit and as a composite within 25m of the pit suggest considerable spatial variation in values exists.

The exchangeable K values of the tested soils all tend to be on the lower scale of the normal soil test ranges (Table 5.6). The Umukuri soil with an averaged value of 0.75 me/100g in the top ten centimetres is the only topsoil that falls within the normal range. The low level of exchangeable K in the Sherry soil is rather strange due to the granitic parent material of the soil being high in K bearing minerals such as orthoclase, microcline and muscovite. Total K in the parent material (see section 5.7) is also higher than for other soils. The results indicate that Sherry soils are derived from granitic materials that have been deeply weathered before erosion and deposition as alluvial fans. The texture of the Sherry soil (coarse sand) also may also affect the exchangeable K in the soil.

All the sampled soils, except the Sherry soil have adequate levels of exchangeable Ca in the upper horizons. The low values of Ca in the Sherry soil are probably due to this soil being derived primarily from granite (little calcium). The other soils would have got adequate amounts of calcium from the limestone and marble in their parent material.

The topsoils of the sampled soils, except the Sherry soils are within the normal range of 1-3 me/100g for exchangeable magnesium. However, subsoils values are often much lower. The Riwaka soil has the highest overall level of exchangeable Mg at 3.61

me/100g. The topsoil horizons in the Umukuri and Ferrer soils also have satisfactory levels of exchangeable Mg, but levels in the lower horizons and may be deficient. The Sherry soil recorded values that were all below the desired range. The values ranged from an average value of 0.65 me/100g in the top 10 cm down to values as low as 0.1 me/100g in the lowest horizon. The Sherry soil is therefore very deficient in Mg, which is probably due to its granitic parent material.

All of the sampled soils fell within the normal range of Na levels. All results were at the lower end of this range ranging as low as 0.1 me/100g in the 36-61 cm horizon of the Umukuri soil, up to 0.16 me/100g in the upper and lower horizons of the Ferrer soil. The higher levels of Na in the Ferrer soil may be due to its closer proximity to the coast, and also possibly due to salinity in the groundwater, especially the increased values of Na at depth (which is close to the water table).

5.6 Phosphate

5.6.1 Introduction

Phosphate (P) is an import element in plant growth as it is involved in many processes, but most importantly it is used for the transfer and storage of energy obtained from photosynthesis. Without an adequate supply of P, plant growth is stunted and the formation of fruits and seeds is reduced. P is stored in the soil solution in the forms of $H_2PO_4^-$ in acid soils, and HPO_4^{2-} in basic soils. The availability of P is also dependant on pH. A pH of 6.5 is generally regarded as the optimum value for maximising the availability of P for the use by plants (figure 5.1).

Olsen P test

This test was designed in New Zealand some twenty-five years ago to estimate the ability of the soil to provide plants with phosphate. The test has been specifically designed to test the likely reaction of the soil to the addition of superphosphate fertiliser. Each individual crop has its preferred level of Olsen P (Table 5.8).

Crop	*Normal Olsen P range*
Apples/pears	30-60
Stone fruit	15-35
Blackcurrants	15-30
Raspberries	40-60
Strawberries	30-40
Kiwifruit	30-60
Grapes	15-40
Citrus	30-50
Feijoas	30-50

Table 5.8. Normal Olsen P range (ugP/ml) for selected crops (Hill Laboratories, 2002).

Phosphate retention test

This is a test that provides an idea of a soils ability to fix phosphate. This is important as it gives a guide to how well a soil is able to retain P, and the level of buffering it has. P retention can be divided up into three classes: low (0-30%), moderate (31-85%) and high (86-100%) (McLaren and Cameron, 1996).

5.6.2 Results

The Riwaka, Umukuri and Sherry soils all generally tend to have decreasing values of both Olsen P and P retention with depth, whereas the Ferrer soil has fairly constant levels of both Olsen P and P retention throughout the profile (Table 5.9). Olsen P values are the highest in the topsoil (0-10 cm pit) of the Umukuri soil where a value of 71 μgP/ml was found. The Sherry soil has the lowest levels of Olsen P, with just 1.4 μgP/g in the lowest horizon (92-100 cm).

The Riwaka soil has levels that range between 32.9 and 34.3 μgP/g in the topsoil, but decreases to a range of between 8.6 and 10.5 μgP/g in the subsoil. The P retention was also higher in the topsoil with values ranging between 21.9 and 24.1%, while the subsoil values ranged between 16.5 and 17.5%.

The Olsen P of the Umukuri soil is 71.0 μgP/g in the top 10 cm, decreases to 27.6 μgP/g in the base of the topsoil, and 7.6-13.8 μgP/g in the subsoil. P Retention values ranged between 12.1 and 20.4% in the topsoil and 7.0 and 16.9% in the subsoil.

The Sherry soil Olsen P is 32.9 μgP/g in the top 10 cm, 13.8 μgP/g in the base of the topsoil, and 1.4 to 13.8 μgP/g in the subsoil. P Retention values range between 18.9 and 23.0% in the topsoil and 6.4-20.2% in the subsoil.

The Olsen P and P retention of the Ferrer soil is higher than the other three sampled soils with values ranging between 26.7 and 52.4 μgP/g, and 33.6 and 40.2% respectively.

Riwaka	Olsen P	P Retention	Umukuri	Olsen P	P Retention	Sherry	Olsen P	P Retention	Ferrer	Olsen P	P Retention
0-10 cm comp	34.3	24.1	**0-10 cm comp**	61.9	18.8	**0-10 cm comp**	32.9	23.0	**0-10 cm comp**	41.1	39.0
0-10 cm pit	33.8	21.9	**0-10 cm pit**	71.0	12.1	**0-10 cm pit**	24.3	20.0	**0-10 cm pit**	47.6	36.5
10-38 cm	32.9	22.9	**10-28 cm**	42.9	20.4	**10-26 cm**	13.8	18.9	**10-32 cm**	26.7	40.2
38-70 cm	8.6	17.5	**28-36 cm**	27.6	21.4	**26-47 cm**	7.6	6.4	**32-51 cm**	46.7	33.6
70-110 cm	10.5	16.5	**36-61 cm**	13.3	16.9	**47-70 cm**	2.9	17.3	**51-93 cm**	52.4	34.0
			61-78 cm	13.8	15.1	**70-92 cm**	2.4	20.2	**93-120 cm**	42.4	36.7
			78-101 cm	7.6	7.0	**92-100 cm**	1.4	10.6			

Table 5.9. Olsen P (μgP/g) and P retention (%) values for sampled soils.

5.6.3 Discussion

The topsoils of the sampled soils (Table 5.9) are within or above the normal range for recommended Olsen P values for the crops listed in table 5.6. However, a low value of 13.8 μgP/g is present in the lower topsoil (10-26 cm) of the Sherry soil. The Olsen P values of all the subsoils are at levels below the normal ranges, with the exception of the Ferrer soil where values remain similar to the topsoil.

Of the sampled soils, all with the exception of the Ferrer soil are classified as having low phosphate retention. The Ferrer soil is classified as a medium level of P retention, with values ranging from as high as 40.2% in the 10-32 cm horizon (lower topsoil), to a low of 33.6% in the horizon below this (32-51 cm). The P retention and Olsen P of this soil is unusual. Firstly the Olsen P of most soils decreases with depth, a result of decreased organic matter and higher fertiliser application nearer the surface. Secondly the P retention of imperfectly to poorly drained soils is usually lower than adjacent soils with similar parent material that are well drained.

This pattern of decreasing Olsen P with depth is expected due to the higher concentration of organic matter and the more weathered soil particles in the upper horizons. The uniform readings in the Ferrer soil could be due to the ferro-organic-clay coatings present.

5.7 XRF Analysis of sediments

5.7.1 Introduction

X-ray fluorescence (XRF) analyses of the sampled soils was undertaken by SpectraChem Analytical Limited, Lower Hutt. This was done so that an understanding of the parent materials that form the soils could be established and/or reaffirmed. Samples were taken from the lower horizon of each sampled profile, as this is where the least weathering has occurred, and therefore provides the best representation of the parent material. There was some variation in the texture of the collected samples, with the Ferrer soil sample a silt loam, the Riwaka soil a fine sandy loam, the Sherry soil a coarse sand, and the Umukuri soil a medium loamy sand.

5.7.2 Results

There are significant differences between soils, especially between the Sherry and the other three sampled soils (table 5.10). The Sherry soil showed substantially lower levels of both iron and manganese oxides (Fe_2O_3 and MnO respectively). Levels of magnesium and titanium oxides (MgO and TiO_2 respectively) in the Sherry soil are also a lot lower than in the other soils tested.

The results of the trace element analyses (table 5.11) show the Sherry soil has increased levels of barium (Ba) and decreased levels of chromium (Cr), copper (Cu), lanthanum (La), nickel (Ni), zinc (Zn) and zirconium (Zr) compared to the other three soils sampled.

MAJOR OXIDE ANALYSES				
Oxide	**Riwaka 70 - 110**	**Umukuri 78 - 101**	**Sherry 92 - 100**	**Ferrer 93-120**
SiO_2	66.51	58.60	74.12	52.26
Al_2O_3	14.73	13.94	14.63	18.71
Fe_2O_3	5.62	9.14	0.45	9.77
MnO	0.09	0.15	<0.01	0.16
MgO	2.01	3.51	0.11	3.67
CaO	1.60	5.60	1.49	4.08
Na_2O	2.65	3.22	4.27	2.39
K_2O	2.06	1.97	3.48	1.24
TiO_2	0.73	2.35	0.18	1.32
P_2O_5	0.13	0.31	0.02	0.36
LOI	3.64	1.09	0.71	5.99
SUM	99.77	99.88	99.44	99.95

All values are expressed as weight % on oven dried [110°C] basis.
LOI = loss on ignition at 1000°C.

Table 5.10. Major oxide analyses on the subsoil of the sampled soils.

TRACE ELEMENT ANALYSES				
Element	**Riwaka 70 - 110**	**Umukuri 78 - 101**	**Sherry 92 - 100**	**Jenkins 93-120**
As	5	2	<1	2
Ba	570	655	1302	523
Ce	57	65	97	90
Cr	199	131	<1	133
Cu	28	29	<1	97
Ga	17	18	15	23
La	26	24	<1	44
Nb	9	17	4	10
Ni	112	45	5	81
Pb	23	14	16	16
Rb	84	51	67	44
Sc	15	21	<1	19
Sr	312	875	804	618
Th	13	2	<1	7
U	6	5	5	5
V	104	210	<1	209
Y	23	19	4	22
Zn	72	82	18	119
Zr	197	311	77	152

All values are expressed as mg/kg.

Table 5.11 Trace element analyses on the subsoil of the sampled soils.

5.7.3 Discussion

The levels of iron and manganese oxides in the Riwaka, Umukuri and Ferrer soils indicate that the parent material is possibly from felsic (granite), sandstone, limestone or dolomite rocks. Levels of magnesium and titanium oxides (MgO and TiO_2 respectively) in the Sherry soil are a lot lower than the others, indicating that the parent material is more likely to be dominated by granite. The results of the trace element analyses further enforce the findings found in the major oxide analyses. This reinforces the presumed assumption that the Sherry soil is primarily derived from granite, whereas the other three soils have come from more complex and generally more basic or iron rich rocks.

The relatively low level of calcium in the Riwaka soil is surprising as marble is common in the catchment. It was expected that levels would be substantially higher than the Sherry soil.

CHAPTER SIX

Land Evaluation

6.1 Introduction

Land evaluation is a process where the physical factors of a particular area are related to a particular land use. This involves identifying and classifying the individual characteristics of a site such as climate, topography, and soil type, and then correlating these characteristics to possible land uses. In essence it provides a comparison of a particular piece of land for a particular land use, relative to another piece of land for the same land use. The key areas where land evaluation has a direct application are with land resource planning, guiding land purchase, and the basing of decisions on land management (Webb and Wilson, 1995). Two useful manuals on this process are 'A manual of land characteristics for evaluation of rural land' (1995) and 'Classification of land according to its versatility for orchard crop production' (1994) by Webb and Wilson at Landcare Research.

6.1.1 Soil Versatility

Soil versatility is a measure of the ability of the soil to be used for many different land uses. Very versatile soils are suited to a wide range of uses, including cultivation and cropping which are very demanding on soil. Molloy (1998) describes a versatile soil as one that:

- occurs on flat land or very gentle slopes (<5°);
- has a potential rooting depth of at least 0.75m;
- offers little resistance to root penetration
- suffers few days of soil-water deficit;

- suffers few days of waterlogging;
- has large, interconnected pores to ensure good drainage and aeration;
- has a low content of stones;
- is capable of being cultivated by machines throughout most of the spring period;
- has high structural stability; *and*
- is not likely to suffer from erosion, flooding or salt contamination.

Versatile soils not only support the greatest range of land uses but also have the best energy-use efficiency for crop production, the strongest absorption capacity of pollutants (minimising contamination risk), and the greatest resistance to land disturbance (Landcare Research, 1999). Versatile soils are commonly classified according to their description under the New Zealand Land Resource Inventory (NZLRI). Land that is classified with a Land Use Capability (LUC) class of I or II and sometimes III is often classified as versatile.

The land use capability of the study area is very high (figure 6.1). Values range from a significant area of class 1 land on the floodplain of the Motueka River and up the Riwaka Valley, to a small area of class 8 land near the mouth of the Motueka River. Most of the land in the study area has a LUC class 1, 2 or 3. The re-examination of the soils in this study suggests that some re-designation of the class 1 land may be required.

The NZLRI system has a major weakness when used for the classification of highly productive land, in that it fails to fully quantify highly versatile land. This is due to the purpose the NZLRI was primarily developed for, i.e. for being a tool to evaluate more marginal land that was prone to problems such as erosion. The manuals developed by Webb and Wilson mentioned in section 6.1 are more suited to classifying the land characteristics in terms of their ability for productive enterprises. They also offer the opportunity to semi-quantify suitability, using actual soils data, whereas the LUC is interpretative. In the manual on the evaluation of rural land there are some 27 different tables that can be consulted for the purpose of land classification. Often, though, the data required to support these tables is unavailable or unmeasured.

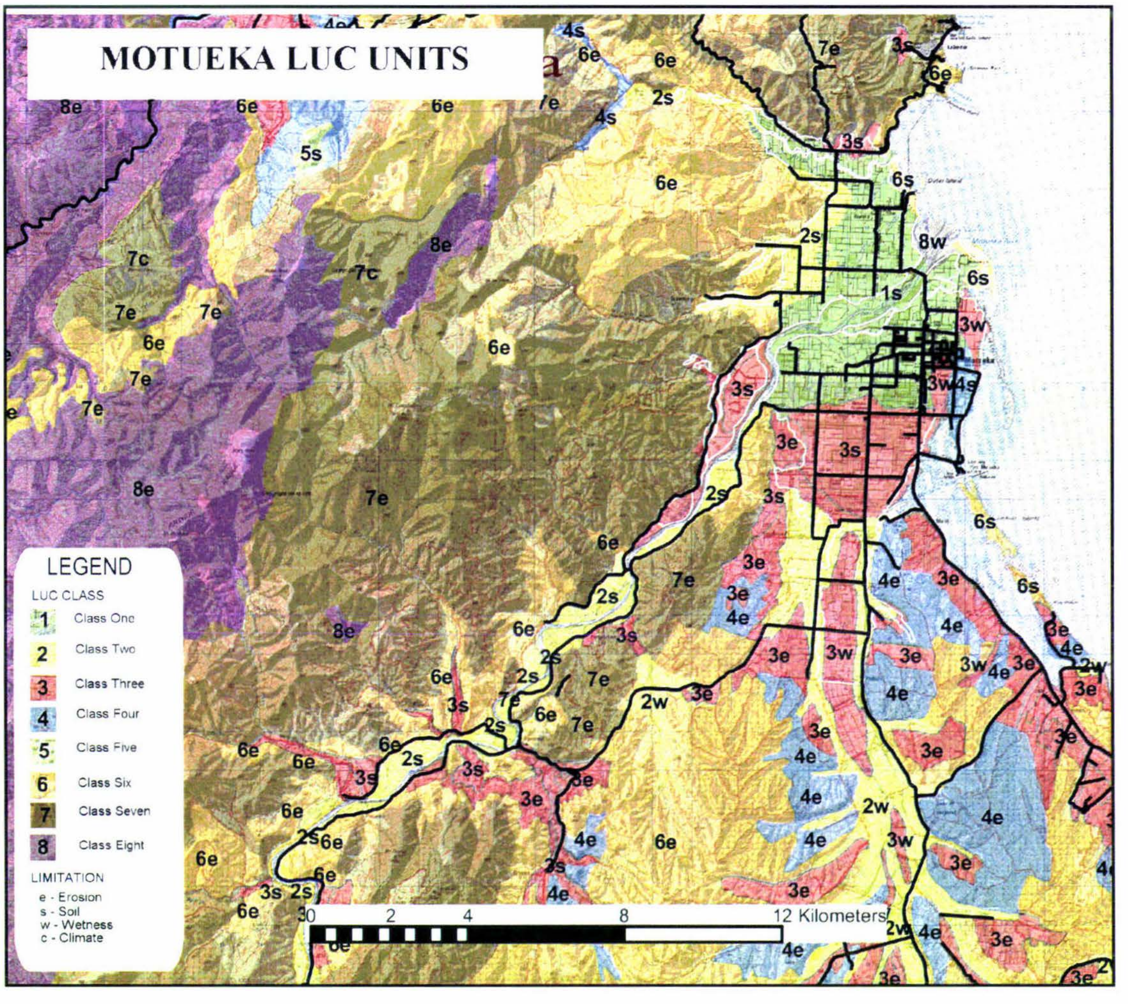


Figure 6.1. LUC units of the study area and surrounds (Lynn, 1975).

The importance of versatility identification

Once versatile soils have been used for urban development or other non-productive land uses they have been effectively lost from production forever. This problem predominantly occurs as more people move to urban areas on such land, resulting in urban sprawl. This in turn places increased pressure on the remaining areas of productive land.

Fragmentation of land is also becoming an issue due to the current increasing trend of living on life-style blocks (Molloy, 1998). Often such blocks are not used as efficiently or intensively as when they were in productive land uses, as the common land use on such blocks is horse or sheep grazing. Historically the land around Motueka has been subdivided into small blocks during high times of tobacco production. To some degree this may mitigate against a number of larger blocks being subdivided into life-style properties.

The loss or fragmentation of versatile land can result in some land uses that require large continuous blocks of rural land becoming unsustainable both economically and environmentally. For an intensive land use such as vegetable production, only one quarter of the area should be used for production at any one time, with the other three quarters spelled. If land users carry out their activities on insufficient amounts of land, they may try to utilise land that is not well suited to production, or attempt to produce more from the smaller remaining areas of land that are suited to production. These options have a greater potential for adverse environmental effects, such as soil compaction due to increased trafficking.

Fragmenting rural land reduces the options for future land users. If it is possible to maintain large rural land parcels for many years it will give future generations the opportunity to carry out a wide range of potential land uses. This point can be emphasised by the recent success of crops such as kiwifruit, which predominantly are based on reasonably large tracts of highly versatile soils.

6.2 Individual Crop Requirements

Differences in the physical requirements of crops for optimum production can vary considerably. Blueberries for example require a significantly lower soil pH for growth and production compared with most other crops. When evaluating land for potential uses, the requirements of the individual land uses must be factored into the process to ensure a sensible result is found.

For the purpose of this study three crops will be studied and evaluated, these are kiwifruit, hops, and blackcurrants, which are three crops that appear to be increasing in hectarage.

6.2.1 Kiwifruit

Presently there are three key commercial kiwifruit varieties available in New Zealand, which are Hayward, Early Start and Zespri Gold. They all are very similar in the environmental conditions required to produce productive yields. A work calendar (figure 6.2) displays the key growth periods, and when activities occur on the orchard.

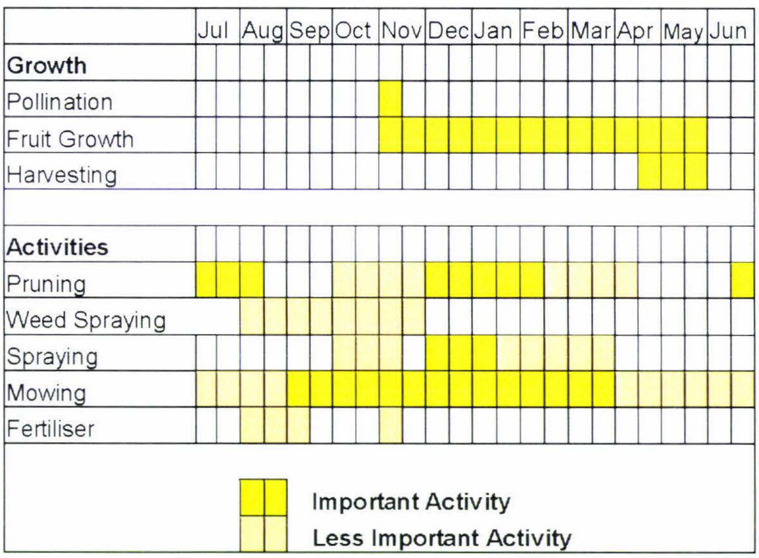


Figure 6.2. Kiwifruit work calendar (*adapted from* Kernohan, 1983).

Climate

Kiwifruit is particularly sensitive to frost and needs a frost-free season of 225 to 240 days. Late spring frosts (colder than -1°C) can damage new shoots, while early frosts in autumn (colder than –2.5°C) can damage fruit and trunks of young vines. Kiwifruit need a lot of moisture in the growing season, and they thrive best when there is an evenly distributed rainfall. They also favour a relatively high humidity, which is the opposite of other crops such as apples and grapes. Annual precipitation is ideally between 1250-2500 mm, and irrigation is needed if below this range (Kernohan, 1983). Hail in the spring can break shoots and reduce crop production. In New Zealand shelter is generally needed to protect kiwifruit from strong winds. This helps to reduce the damage caused when new shoots are growing, and prevents excessive wind rub on the mature fruit (Sale, 1986). Shelter also helps pollination, as bees do not like working in an unsheltered orchard. Insufficient pollination causes large numbers of small "scrub" or misshapen fruit, which decreases profitability (Kernohan, 1983). Strong winds that defoliate the vines also cause the cropping capacity of the next season to be reduced. Table 6.1 displays the climatic data for Te Puke, the heart of the world kiwifruit industry.

	Rainfall (mm)	Temperature Mean (°C)	Min Temp Recorded (°C)	Frost Average Days (ground)	Frost Average Days (air)	Humidity (%)	Hail (days of)	Gale (days of)
JAN	74	18.7	6.5	-	-	76	-	0.1
Feb	111	18.9	5.4	0.1	-	78	-	0.1
Mar	199	17.6	2.7	0.1	-	77	-	0.5
Apr	149	15.3	0.6	1.1	-	81	0.1	-
May	140	12.0	-2.0	9.4	0.4	82	0.1	0.1
Jun	188	9.9	-1.8	12.4	1.3	85	-	0.3
Jul	190	9.3	-2.0	13.9	2.5	84	0.6	0.3
Aug	156	10.2	-1.3	12.1	0.3	82	0.5	-
Sep	153	11.7	-0.3	8.5	0.3	77	0.3	-
Oct	149	13.4	0.8	3.8	-	74	0.4	-
Nov	125	14.9	1.5	1.8	-	75	0.1	-
Dec	120	16.9	4.8	-	-	75	0.4	-
Annual	**1754**	**14.1**	**-2.0**	**63.2**	**4.8**	**79**	**2.5**	**1.4**

Table 6.1. Climatic data for Te Puke (Kernohan, 1983).

Soils

Kiwifruit vines are very sensitive to wet soils so they must be free draining and have a minimum winter water table of 1m. Kiwifruit require good soil fertility, similar to that required by other orchard crops. Soils must contain minimum salts, and not be too alkaline (greater than pH 7.3). Soil for kiwifruit vineyards should have less than 0.25 ppm boron, low sodium, and an electrical conductivity of 0.75 or less (Beutel, 1990).

Classification of the normal range of soil chemical characteristics for kiwifruit growth has been defined by Hill Laboratories (table 6.2).

Element (unit)	Normal Range
pH	5.8 - 6.5
Olsen P (ug/ml)	30 - 60
Potassium (me/100g)	0.60 - 1.20
Calcium (me/100g)	6.0 - 12.0
Magnesium (me/100g)	1.00 - 3.00
Sodium (me/100g)	0.00 - 0.40
CEC (me/100g)	12.0 - 25.0

Table 6.2. Soil chemical requirements for kiwifruit (Hill Laboratories 2002).

6.2.2 Blackcurrants

New Zealand produces 2500-3000 tonnes of blackcurrants annually, with the major cultivars being Magnus, Ben Rua, and Ben Ard (Snelling and Langford, 2002). The two regions where this crop is predominantly grown are Nelson and Canterbury.

Climate

Blackcurrants require a substantial amount of winter chilling, and are best suited to regions in New Zealand that have at least 1300 hours below 7°C (Snelling and Langford, 2002). Because of this, blackcurrants can be grown in shadier spots where many other horticultural crops cannot.

Soil

There have not been significant studies in New Zealand on determining the soil requirements of blackcurrants. Much of the currently utilised research in New Zealand has been either carried out in Britain or Eastern Europe (Clark *et al.*, 1986). Blackcurrants are a tolerant and hardy crop and can survive well in heavier textured soils (e.g. clays) where other berry crops cannot, but do not tolerate wet, water-logged soils (Ballinger and Ballinger, 1981). The normal range of soil nutrients for optimum production of blackcurrants in New Zealand is shown in table 6.3.

Element (unit)	Normal Range
pH	5.8 - 6.5
Olsen P (ug/ml)	15 - 30
Potassium (me/100g)	0.60 - 1.20
Calcium (me/100g)	6.0 - 12.0
Magnesium (me/100g)	1.00 - 3.00
Sodium (me/100g)	0.00 - 0.40
CEC (me/100g)	12.0 - 25.0

Table 6.3. Soil chemical requirements for blackcurrants (Hill Laboratories, 2002).

6.3.2 Hops

Hops are a unique crop, and are only grown in the Nelson/Motueka region in New Zealand. Currently there are 26 growers producing 800 tonnes of hops on approximately 350 ha (MAF, 1997). The current dominant varieties grown in New Zealand are Super Alpha, Green Bullet, and Pacific Gem. All these varieties have been bred for New Zealand conditions.

Climate

Climate is very important to the successful production of hops. This is due to the vulnerability of hops to wind damage when they have fully grown and are strung up some ten metres above the ground. Lack of strong winds during November-February is therefore vital for the production of hops. Hops are also vulnerable to spring frosts that are greater than -5°C. These frosts stop the growth of the bine (the vine) and kill the leaves.

Soils

There has been very little research into the soil factors that dictate optimum hop yields in New Zealand, primarily due to the relatively small area in hop production. From soil studies by Laffan (1975) it has been found that that hops produce highest annual yields on the Riwaka sandy and silt loams, where 2400kg/ha of hops were produced. The Braeburn soils produced significantly less hops, where annual yields of 1350kg/ha were produced. Cases of deficiencies in magnesium, zinc, boron and molybdenum have been noted in New Zealand hops (Oliver, 1962).

6.3 Method of land evaluation

The method of land evaluation involves the rating of climatic, landscape, soil physical and chemical factors of a particular soil to a selected crop. Climatic factors considered for example may include rainfall, temperature and sunshine hours. The factors used are generally restricted to those that have had data collected, which can be a problem, especially as often soil data is unavailable or difficult to obtain.

The ratings for each factor typically range from 1 to 5, with the lowest number indicating the maximum suitability. The amalgamation of these factors can be presented in a table where averages for the key factors (e.g. climate, and landscape) can be presented. These averages are calculated by the addition of the sum of the individual factors, divided by the amount of factors considered.

6.4 Results of land evaluation

The suitability of kiwifruit, blackcurrants and hops were evaluated and rated to the Riwaka silt loam, Umukuri medium sandy loam, Sherry medium sandy loam and Ferrer silt loam soils. Results are summarised in table 6.4, which is a summary of each factor described in appendix A6.

	Riwaka silt loam	Umukuri medium sandy loam	Sherry medium sandy loam	Ferrer silt loam
CLIMATE				
Annual Rainfall	1381	1381	1381	1381
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Annual mean temp	12.5	12.5	12.5	12.5
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Lowest recorded temp	-4.4	-4.4	-4.4	-4.4
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Annual ground frosts	82.0	82.0	82.0	82.0
- Kiwifruit	4	4	4	4
- Blackcurrants	4	4	4	4
- Hops	4	4	4	4
Annual air frosts	30.9	30.9	30.9	30.9
- Kiwifruit	4	4	4	4
- Blackcurrants	4	4	4	4
- Hops	4	4	4	4
Annual sunshine hours	2418	2418	2418	2418
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Annual humidity	77	77	77	77
- Kiwifruit	2	2	2	2
- Blackcurrants	2	2	2	2
- Hops	2	2	2	2
Annual days hail	0.6	0.6	0.6	0.6
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Annual days gale	0.1	0.1	0.1	0.1
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Averages				
- **Kiwifruit**	**1.78**	**1.78**	**1.78**	**1.78**
- **Blackcurrants**	**1.78**	**1.78**	**1.78**	**1.78**
- **Hops**	**1.78**	**1.78**	**1.78**	**1.78**
LANDSCAPE	Riwaka	Umukuri	Sherry	Ferrer
Slope (degrees)	0-3	0-3	5-7	0-3
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1

SOIL PHYSICAL	Riwaka	Umukuri	Sherry	Ferrer
Drainage class	Well	Well	Well	Imperfect to Poor
- Kiwifruit	1	1	1	4.5
- Blackcurrants	1	1	1	3.5
- Hops	1	1	1	2.5
Profile available water (to 1m)	59	114	84	134
- Kiwifruit	3	1	2	1
- Blackcurrants	3	1	2	1
- Hops	3	1	2	1
Bulk Density	1.59	1.36	1.46	1.38
- Kiwifruit	3	2	3	2
- Blackcurrants	3	2	3	2
- Hops	3	2	3	2
Saturated Hydraulic conductivity	3	84	47	4
- Kiwifruit	4	1	2	2
- Blackcurrants	4	1	2	2
- *Hops*	4	1	2	2
Stoniness (% top 1m)	3	0	0	0
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Averages				
- **Kiwifruit**	**2.4**	**1.2**	**1.8**	**2.1**
- **Blackcurrants**	**2.4**	**1.2**	**1.8**	**1.9**
- **Hops**	**2.4**	**1.2**	**1.8**	**1.7**
SOIL CHEMICAL	Riwaka	Umukuri	Sherry	Ferrer
pH	6.3	6.4	5.5	5.5
- Kiwifruit	1	1	4	4
- Blackcurrants	1	1	4	4
- Hops	1	1	4	4
Cation exchange capacity top 60	17.4	10.8	6.75	16.1
cm	3	4	4	3
- Kiwifruit	3	4	4	3
- Blackcurrants	3	4	4	3
- Hops				
Potassium	0.35	0.62	0.10	0.28
- Kiwifruit	3	2	3	3
- Blackcurrants	3	2	3	3
- Hops	3	2	3	3
Calcium	11.0	6.8	2.8	6.9
- Kiwifruit	1	2	3	2
- Blackcurrants	1	2	3	2
- Hops	1	2	3	2
Sodium	0.07	0.02	0.07	0.11
- Kiwifruit	1	1	1	1
- Blackcurrants	1	1	1	1
- Hops	1	1	1	1
Magnesium	1.76	2.75	0.45	1.20
- Kiwifruit	1	1	3	1
- Blackcurrants	1	1	2	1
- Hops	1	1	2	1
P Retention (%) top 20 cm	23	26	20	39
- Kiwifruit	4	4	4	3
- Blackcurrants	4	4	4	3
- Hops	4	4	4	3
Averages				
- **Kiwifruit**	**2.00**	**2.14**	**3.14**	**2.43**
- **Blackcurrants**	**2.00**	**2.14**	**3.00**	**2.43**
- **Hops**	**2.00**	**2.14**	**3.00**	**2.43**
Total Averages				
- **Kiwifruit**	**1.95**	**1.73**	**2.18**	**2.02**
- **Blackcurrants**	**1.95**	**1.73**	**2.14**	**1.97**
- **Hops**	**1.95**	**1.73**	**2.14**	**1.93**

Table 6.4. Factor evaluation of selected crops to selected soils.

Climatic variations between soil types are minimal. The climatic conditions of the study area is generally highly suitable for the studied crops, however the occurrence of ground and air frosts is the most limiting factor with a rating of 4.

The only landscape factor considered (slope) was rated 1 on all soils.

The soil physical factors varied substantially from soil type to soil type. The Umukuri medium sandy loam was by far the most suitable soil for the studied crops, and scored a 1 for each factor considered, with the exception of bulk density, which scored a 2. The next best soil physically was the Sherry medium sandy loam, with an averaged rating of 1.8. This soil scored well in drainage class and stoniness, but has lower readily available water and saturated soil hydraulic conductivity with ratings of 2, and bulk density with a rating of 3. The Riwaka silt loam rated similarly to the Sherry soil, but the poorer ratings of 2 for readily available water and saturated hydraulic conductivity increased to 3 and 4 respectively. The Ferrer silt loam rated well in the available water and stoniness, but poorly in the drainage, bulk density and saturated soil hydraulic conductivity. Values for the drainage class of the Ferrer soil varied with crops, with kiwifruit rating 4.5, blackcurrants 3.5 and hops 2.5. All the crops scored 2 for saturated hydraulic conductivity in the Ferrer soil.

The soil chemical properties of all the soils rate as only moderate, with averages ranging between 2 and 3.14. The Riwaka soil rated best with good scores for pH, calcium, sodium and magnesium levels. A rating of 3 was given to CEC and potassium, and a 4 was given for phosphate retention. The ratings for Umukuri and Ferrer soils were slightly lower. Sodium and magnesium were given ratings of 1. pH was rated as 1 in the Umukuri soil, but received a 4 in the Ferrer soil. A rating of 2 was given to both soils for calcium. CEC in these soils was rated poor with a 4 and 3 given to the Umukuri and Ferrer soils respectively. Potassium was rated 2 and 3, and phosphate was rated 4 and 3 in these soils. The poorest soil was the Sherry medium sandy loam. Sodium levels were the only chemical property that was rated with a 1. Magnesium levels were rated as 2 for black currant and hop production, but 3 for kiwifruit production. Ratings of 3 were given for potassium and calcium levels, and ratings of 4 were given for pH, CEC and phosphate retention.

In general results of the total averages for the soil ratings are very similar ranging from 1.73 to 2.18. The Umukuri and Riwaka soils are rated the best with a scores 1.73 and 1.95 respectively. Soil physical factors were rated higher for the Umukuri soil with an average of 1.2 compared to 2.4 in the Riwaka. The chemical properties of the Riwaka soil rated better than the Umukuri soil with values of 2.00 and 2.14 respectively. The other two soils investigated also rated similarly with total averages between 2.14 and 2.18 for the Sherry soil and 1.93 and 2.02 for the Ferrer soil. The rating for growing hops on the Ferrer soil is greater than the Riwaka soil. There was also variation between crops on the Sherry and Umukuri soil with hops rating the most suitable, then blackcurrants and kiwifruit respectively. From the factor averages landscape was rated the factor most conducive to the evaluated crops, then climate. Soil chemical and physical factors varied with physical factors rated poorer in the Riwaka soil, but higher in the other three soils.

6.5 Discussion

The averages for each land evaluation factor and the total averages give an insight into the suitability of the crops, as well as the versatility of the soil types. The best soil, with the lowest total average rating is the Umukuri soil, with a rating of 1.73. This indicates that this soil is also the most versatile, and is therefore able to support the widest range of crops. The second best rated soil is the Riwaka, with a total averaged rating of 1.95. The Ferrer soil with a total averaged rating ranging between 1.93 for hops and 2.02 for kiwifruit was rated third. The suitability of hops is in fact greater on the Ferrer soil than the Riwaka soil. This is due to the soil physical suitability of this soil. The Sherry soil had the worst total average with a rating of 2.14-2.18.

There is no data to indicate any major climatic differences within the study area. The ratings for climatic factors indicate the soils are all similar, with a value of 1.78. This value would be a lot higher if it was not for the occurrence of both air and ground frosts. There is likely to be variation in the location of frosts with pockets and zones existing. These areas are likely to be the valleys, and the land in general as distance from the sea increases. The impact of frosts is likely to be the biggest climatic restriction to the development of new crops in the region.

As the only landscape factor considered was slope, the landscape is highly suitable for the studied crops with a rating of 1.

There was considerable variation from soil to soil in the physical ratings. The Umukuri soil was rated as the best soil. This is due to the texture of the soil, which enables free drainage, but also holds adequate water. The Riwaka soil rated the poorest with an averaged rating of 2.4. This is likely to be due to the high bulk density of the soil, which in turn causes saturated hydraulic conductivity to be slow. Profile available water is also rated poorly. This shows a weakness in this method used as the physical characteristics of the Riwaka soil is likely to be more highly suited than the Ferrer soil for the production of a crop such as kiwifruit.

The chemical ratings also varied from soil to soil. Riwaka soil was the best with an average rating of 2. P retention, CEC and available K though are low raising the rating. The Sherry soil is the poorest soil chemically with ratings ranging between 3.00 and 3.14. This is probably due to the coarse nature of the soil.

Chapter Seven

Soil Survey Report

Please Note:

This chapter has been set out in a form that enables it to exist by itself, in the form of a 'soil survey report'. For this reason there is material in this section that has already been mentioned in other chapters of the thesis. However, there is also a considerable amount of material within this chapter that is not mentioned elsewhere.

A description of

The Soils of Part Motueka, South Island, New Zealand

P J Nelson

INTRODUCTION

LOCATION

The study area covers some 4355 ha around the Motueka township, at the northern end of the South Island, New Zealand. The area covered by this map is restricted to the flat (<7°) alluvial land, and excludes any of the rolling land in the area. The area is bounded by Tasman Bay in the east, the Tasman Bay Mountains in the north-east, and the Moutere Gravel formation in the south. The major rivers in the area are the Motueka and Riwaka. The Motueka River (2200 km^2) is a substantially larger river the Riwaka (7km^2) and is the source for the majority of the sediment that forms the plains.

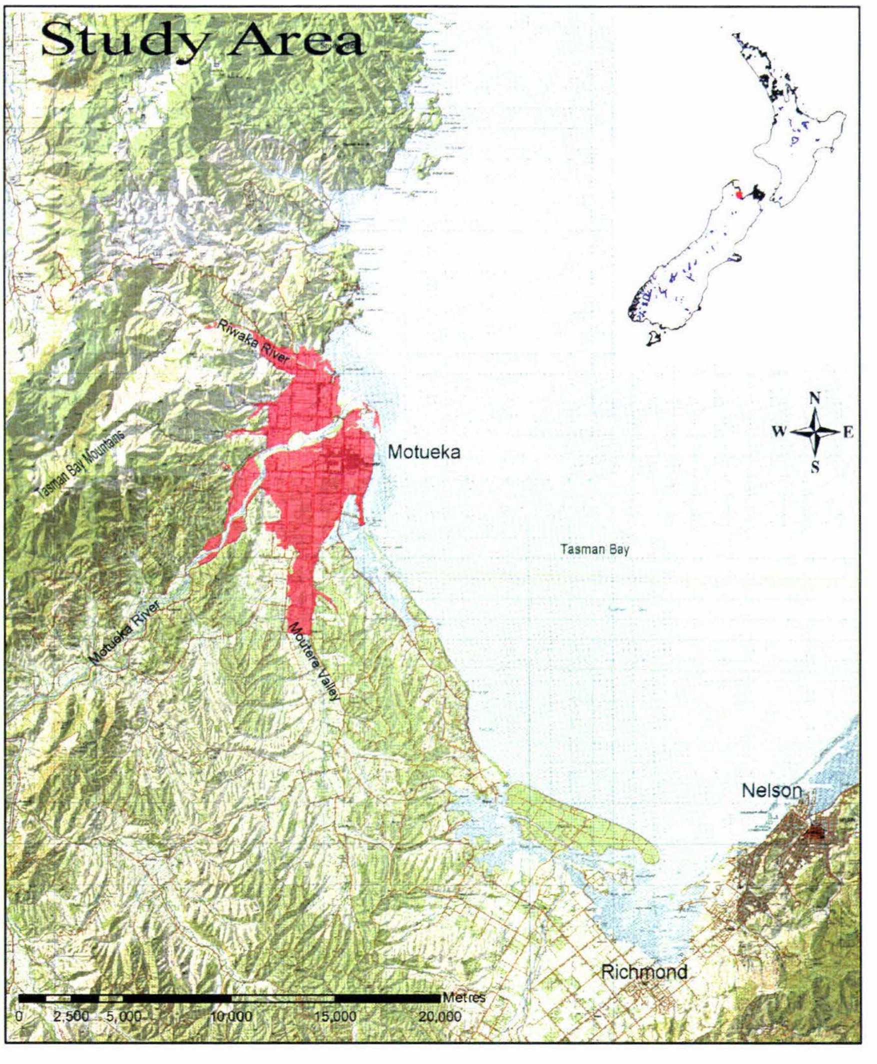


Figure 1. Location of the Motueka soil map.

GEOLOGY

The geology of the region can be defined into two distinct units. These are the Moutere Gravel formation that forms the southern rolling hill country, and the many differing geological units that form the remaining Mountainous parts of the region.

The Late Pliocene to Early Pleistocene Moutere Gravel formation is made up of uniform, horizontally bedded, well rounded pebbles and cobbles of quartzose greywacke, which are held within a clay-sand matrix (Rattenbury *et al.*, 1998).

The remaining area has varied geology. The northern hills are predominantly Early Cretaceous granites, while the southern mountains are predominantly Early Permian ultra-mafic formations and the south-east is dominated by Triassic sandstone/siltstone units. Ordovician limestone, marble, and Middle Devonian calcareous mudstone dominate in the west (Rattenbury *et al.*, 1998).

The geology has influenced the alluvium deposited on the plains (Table 1). The Sherry soil, formed predominantly of granitic parent material, has substantially lower levels of iron (Fe_2O_3), magnesium (MgO), titanium (TiO_2) and phosphorus (P_2O_5), but more potassium (K_2O) and silica (SiO_2). The Umukuri soil, from more basic rocks, has lower potassium, but higher iron and calcium. The Riwaka and Ferrer soils are derived from mixed alluvium of the Motueka River.

MAJOR OXIDE ANALYSES

Oxid	Riwaka 70 - 110	Umukuri 78 - 101	Sherry 92 - 100	Ferrer 93-120
SiO_2	66.51	58.60	74.12	52.26
Al_2O_3	14.73	13.94	14.63	18.71
Fe_2O_3	5.62	9.14	0.45	9.77
MnO	0.09	0.15	<0.01	0.16
MgO	2.01	3.51	0.11	3.67
CaO	1.60	5.60	1.49	4.08
Na_2O	2.65	3.22	4.27	2.39
K_2O	2.06	1.97	3.48	1.24
TiO_2	0.73	2.35	0.18	1.32
P_2O_5	0.13	0.31	0.02	0.36
LOI	3.64	1.09	0.71	5.99
SUM	99.77	99.88	99.44	99.95

All values are expressed as weight % on oven dried [110°C] basis.
LOI = loss on ignition at 1000°C.

Table 1. XRF major oxide analyses of the subsoils of four key soils in the study area.

CLIMATE

The climate for the Nelson region is unique (Table 2). It is significantly warmer and sunnier than its latitude might suggest, primarily due to the effects of the surrounding mountain ranges. Riwaka gets on average an annual amount of 2418 sunshine hours, 57% of the total possible hours. Annual rainfall is 1381 mm, and the mean temperature is 12.5°C. Frosts are common with 82 days of ground frosts annually. Other features such as gales and hail are very rare.

	Rainfall (mm)	Temperature Mean (°C)	Min Temp Recorded (°C)	Frost Average Days (ground)	Frost Average Days (air)	Humidity (%)	Hail (days of)	Evaporation mm (pan)	Mean Annual Sunshine hours	Gale (days of)
Jan	74	17.4	4.2	-	-	68	-	179	264	-
Feb	88	17.4	2.2	0.1	-	72	-	141	243	-
Mar	100	16.0	1.3	0.4	-	77	-	106	204	-
Apr	135	13.2	-0.6	3.4	0.1	81	-	68	180	-
May	146	10.1	-3.3	10.9	2.4	85	0.1	37	165	-
Jun	125	7.7	-3.8	17.9	8.8	87	-	28	146	-
Jul	148	7.0	-4.4	19.3	11.4	92	-	27	157	-
Aug	153	8.0	-4.4	16.1	6.6	85	0.1	39	164	-
Sep	109	10.2	-2.6	9.5	1.4	77	0.1	65	183	-
Oct	122	12.3	-1.8	3.6	0.2	69	-	105	232	-
Nov	91	14.2	0.4	0.7	-	67	0.2	141	234	-
Dec	90	16.2	2.5	0.1	-	67	0.1	169	246	0.1
Annual	**1381**	**12.5**	**-4.4**	**82.0**	**30.9**	77	**0.6**	**1105**	**2418**	**0.1**

Table 2. Climatic data for Riwaka (NZMS, 1985).

VEGETATION

Pre-European vegetation of the region was commonly forest. Beech (*Nothofagus spp.*) forest dominated the steep slopes of the valleys, while podocarps were abundant in the higher rainfall areas, gullies and on the lowlands (Chittenden *et al.*, 1966). The stony Hau soils to the south-west of Motueka township were not forested, and manuka, bracken, and grasses dominated. Maori settlement in the area did have a significant impact on pre-European vegetation due to the burning and development of gardens. The coastal belt near Motueka was not forested, thought to be due to the impacts of pre-European Maori activities (Chittenden *et al.*, 1966).

Much of the vegetation now is high producing horticultural crops such as apples, kiwifruit and hops. Apples are the most dominant land use with 1489 ha or 30% of the study area in this land use. Pasture is also significant with 1419 ha, but much of this is the poorer land with gravelly or drainage limitations, and is therefore unsuitable for intensive horticulture. The areas in kiwifruit and hops are also substantial with 583 and 256 ha respectively. Motueka township and other buildings occupy 20% of the study area.

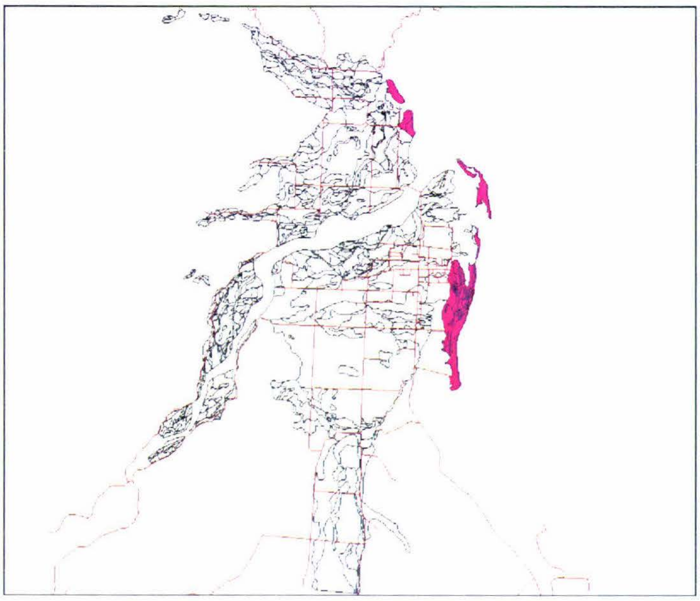
SOIL SURVEY

The soil map used as a basis for this study was re-discovered by the Tasman District Council (TDC), with the date and author unknown. The map (scale approx. 1:36,000) itself is poorly explained and contains very little description, with only an accompanying hand written A4 sheet which could not be interpreted as either a physiological or pedological legend. No accompanying publication or report describing the soil units on the map was found.

During this study extensive ground augering was undertaken to validate the map. Detailed sampled areas were selected based on replies to an introductory letter sent out to landowners. This approach was undertaken due to the limited time available for this study.

Further analysis of four soils was also undertaken. These were the Riwaka, Umukuri, Sherry and Ferrer soils, and were selected due to their dominance, and also due to the potential for future horticultural development. Analysis involved physical and chemical factors such as dry bulk density, saturated soil hydraulic conductivity, available water, main nutrients and a XRF on the key macro and micro nutrients.

TAHUNANUI SAND SOIL SERIES (TA)



Key Points

- Located along the coastal foreshore
- Formed on coastal dune formations
- Profile dominated by coarse sand, with little topsoil development
- Four soil types mapped with differing textures
- Mostly excessively drained, with the exception of the wet dune sands which are imperfectly drained

Detailed Description

Tahunanui sands cover much of the coastal belt of the study area, but particularly north of Moutere Inlet. They cover some 213 ha of the Motueka soil map. Much of this unit (77%) is now covered by the Motueka township, or used for non-productive uses such as a sewage treatment plant. The sand north of Motueka township is primarily derived from granitic alluvium, while that south of the township is from a great variety of parent materials (Chittenden *et al.*, 1966).

Four different types are differentiated in this study; the Tahunanui gravelly dune sand (45 ha), Tahunanui fixed dune sand (63 ha), Tahunanui dune sand (73 ha), and the Tahunanui dune sand – wet (32 ha). All these soils have weakly structured to structureless profiles. The gravels in the gravelly dune sand typically occur within 15 cm of the surface. Topography is generally flat to rolling.

Soil Profile

A typical soil description of the Tahunanui fixed dune sand extracted from Chittenden *et al.* (1966) is:

10 in. (25 cm)	*dark grey fine sand, very friable, very weakly developed medium nutty structure;*
6 in. (15 cm)	*pale greyish brown fine sand, weakly compacted, structureless;*
on	*pale brown fine sand, loose, structureless.*

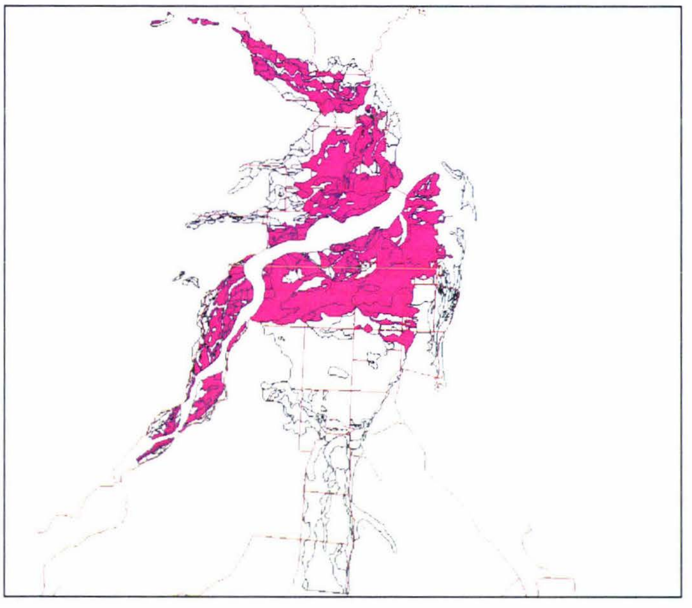
General Physical Properties

The physical properties of this soil are those that are expected for coastal dune soils. Water holding capacity is low, saturated hydraulic conductivity is rapid, and structure is weak to structureless.

General Chemical Properties

The chemical properties of this soil are poor. Fertility is low, pH is near neutral and availability of nutrients such as phosphorus and potassium are very low.

RIWAKA SOIL SERIES (RI)



Key Points

- Dominant soil on the Motueka soil map
- Located on the floodplains of the Riwaka and Motueka Rivers
- Mixed alluvial material from these catchments
- Typically well drained but also areas of excessive drainage
- 19 different soil types based on texture

Detailed Description

Riwaka soils are the dominant soils in the study area, covering 2032 ha of the Motueka and Riwaka Rivers floodplains, as well as the corresponding valley floors. They are formed from alluvium derived from many assorted rock types including greywacke, granite, limestone, quartzite and basic igneous rocks. The alluvial material from the Riwaka and Motueka River catchments is very similar, and hence is all classified as Riwaka soils. There are numerous small side catchments, especially up the Motueka River, where alluvium is of considerably different composition. These areas have been removed from this soil series and classified separately.

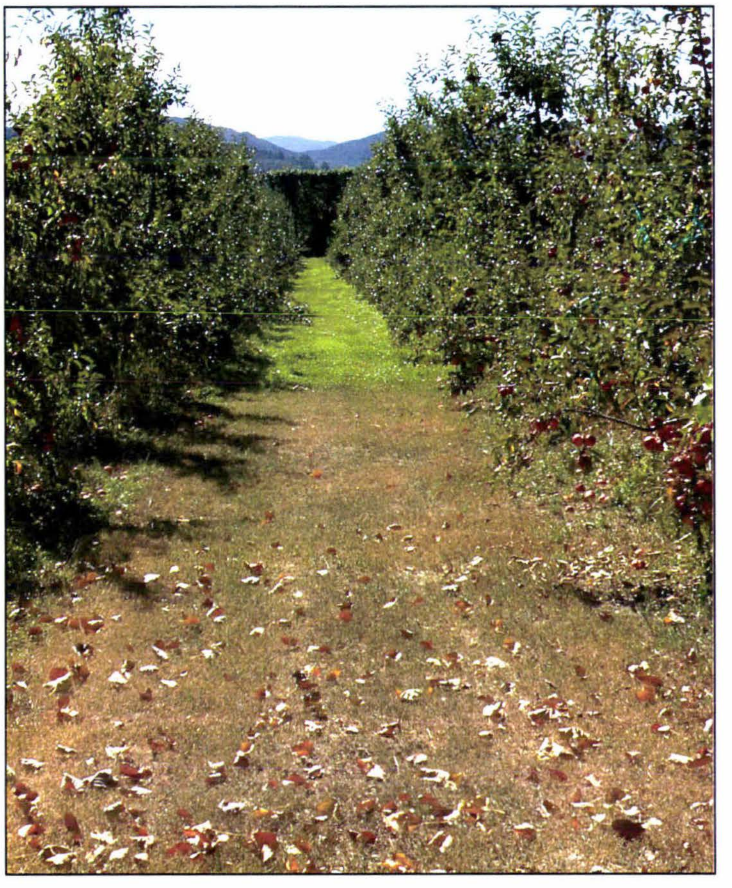


Figure 2. Contrasting grass growth between Riwaka medium sand over gravel (foreground) and Riwaka fine sand (background)

The Riwaka series includes a wide variety of soil types, of different textures, layers of contrasting texture and depth to underlying gravel. This can have a substantial effect on soil properties, especially water holding capacity (figure 2). In all there are nineteen different map units differentiated as Riwaka soils (Table 3), with the silt loam (373 ha) and fine sandy loam (219 ha) dominating. Drainage classes for these soils range between excessive and well drained, with the majority of the soils classified as well drained. All profiles are underlain by gravel or sand.

Type	ha	Drainage	Brief description*
Riwaka coarse sand	3	Excessively	Coarse sand topsoil to 25 cm, over coarse sand
Riwaka coarse sandy loam over gravel	8	Excessively	Coarse sandy loam topsoil to 30 cm, over gravels
Riwaka medium sand	84	Excessively	Medium sand topsoil to 25 cm, over medium sand
Riwaka medium sand over gravel	188	Excessively	Medium sand topsoil to 25 cm over gravel
Riwaka fine sand over gravel	86	Excessively	Fine sand topsoil to 25 cm over gravels
Riwaka medium sand over silt loam	47	Well	Medium sand to 25 cm over silt loam
Riwaka medium sandy loam	61	Well	Medium sandy loam topsoil to 30cm, sandy loam to 60 cm, over gravels
Riwaka medium sandy loam over gravel	97	Well	Medium sandy loam topsoil to 25 cm, over gravels
Riwaka medium sandy loam over sand	106	Well	Medium sandy loam topsoil to 25 cm, over sand
Riwaka medium sandy loam over silt loam	6	Well	Medium sandy loam topsoil to 30 cm over silt loam subsoil
Riwaka fine sand	16	Well	Fine sand topsoil to 25 cm, over fine sand
Riwaka fine sand over silt loam	28	Well	Fine sand topsoil to 25 cm, over silt loam
Riwaka fine sandy loam	219	Well	Fine sandy loam topsoil to 30 cm, over sandy loam subsoil
Riwaka fine sandy loam over gravel	18	Well	Fine sandy loam to 30 cm, over gravel
Riwaka fine sandy loam over sand	67	Well	Fine sandy loam over to 30 cm, over sand
Riwaka fine sandy loam over silt	10	Well	Fine sandy loam to 30 cm over silt
Riwaka silt loam	373	Well	Silt loam topsoil to 32cm, over silt loam subsoil
Riwaka silt loam over gravel	149	Well	Silt loam topsoil to 32cm, over gravels
Riwaka silt loam over sandy loam	226	Well	Silt loam topsoil to 32cm, over sandy loam subsoil

Table 3. Brief descriptions of the Riwaka soils.

General Physical Properties

The physical attributes of these soils are likely to vary greatly, especially in the subsoil. The bulk density of the sampled soil was high, especially in the lower subsoil, reaching values of 1.59g/cm^3 (Table 4), but not all Riwaka soils appeared to be this dense. The saturated soil hydraulic conductivity in the subsoil of the sampled soil was also below desired rates, with values as low as 3 mm/hr. Plant available water is reasonably low with 59.2 mm in the upper 1m of the profile.

* all soils generally overly gravels or sand at depth (80-100 cm)

General Chemical Properties

These soils are the most chemically fertile in the study area, with moderate to high natural fertility (Table 4). The sampled soil is slightly acidic with an average pH of 6.4 throughout the profile. All chemical elements are at desired levels with the exception of potassium (K). Levels of K, especially in the subsoil, are very low, recording as low as 0.04 me/100g in the sampled soil.

Soil properties of the Riwaka silt loam			
	Topsoil	Subsoil	
		Upper	Lower
Bulk density (g/cm^3)	0.98-1.42	1.59	1.59
Saturated hydraulic conductivity ($mm\ h^{-1}$)	22-299	13	3
Readily available water (mm)			
to 50cm depth	42		
to 100cm depth	59		
pH	6.3-6.4	6.3	6.4
CEC (me/100g)	17-23	16	15
P retention (%)	21.9-24.1	17.5	16.5
Base saturation (%)	62-73	54	58
K (me/100g)	0.23-0.54	0.04	0.06
Ca (me/100g)	8.7-14.3	6.3	4.8
Mg (me/100g)	1.36-2.29	2.52	3.61
Na (me/100g)	0.06-0.07	0.05	0.07

Table 4. Physical and chemical properties of the Riwaka soil.

Soil Profile

A brief profile description of the dominant Riwaka soil (see appendix A1 for a full description), the Riwaka silt loam located under an apple and pear orchard, map reference NZMS 260-N27 101099, is:

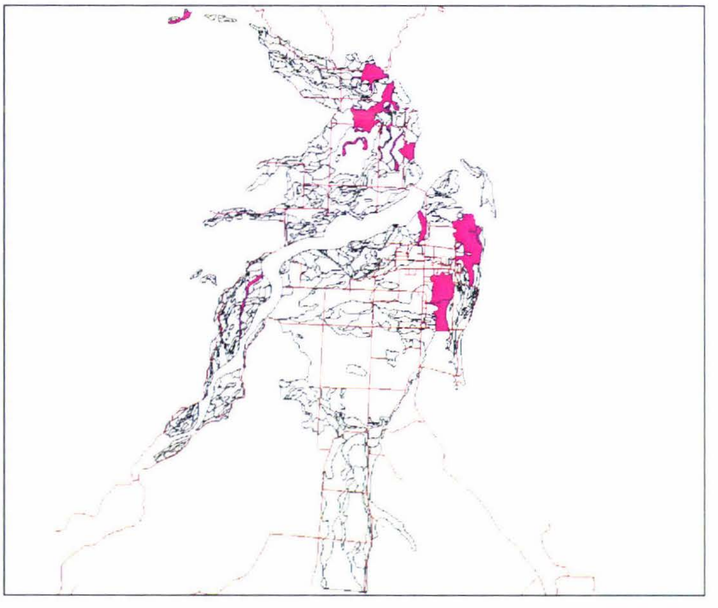
Ap *0-36 cm*
dark greyish brown silt loam; friable; moderately developed, fine nut structure; indistinct boundary

Bw1 *36-72 cm*
light olive brown silt loam; friable; moderately developed, fine nut structure; indistinct boundary

Bw2 *72-105 cm*
light olive brown silt loam; friable; moderately developed, fine nut structure; a few, small stones

105– similar but weakly weathered stones

FERRER SOIL SERIES (FE)



Key Points

- New soil series incorporating imperfectly and poorly drained soils formerly included in the Riwaka and Umukuri series
- Found in low lying areas of the landscape, close to the water table
- Occurs most commonly in the eastern costal parts of the district

Detailed Description

These soils are the imperfectly and poorly drained equivalents of the Riwaka soils. Extensive grey and orange mottling occurs in these soils, commonly up into the topsoil. Five different types are mapped; being coarse sand (24 ha), medium sandy loam over gravel (12 ha), fine sandy loam over gravel (8 ha), silt loam (239 ha), silt loam over gravel (5 ha), and clay loam (51 ha) (Table 5). They cover 296 ha in the study area, and are found in the lower lying areas, generally close to the water table. Artificial drainage has been intensively developed and in some areas the water table has been successfully lowered. Today most forms of land use practiced in the study area are occurring on these soils, but some areas that are still wet remain in pasture.

Type	ha	Drainage	Brief description
Ferrer coarse sand	24	Poorly	Coarse sand topsoil to 25 cm with significant gleying, over coarse sand
Ferrer medium sandy loam over gravel	12	Poorly	Medium sandy loam topsoil to 25 cm with significant gleying, over gravel
Ferrer fine sandy loam over gravel	8	Poorly	Fine sandy loam topsoil to 35 cm with strong gley mottles, over gravel
Ferrer silt loam	239	Poorly	Silt loam topsoil with significant orange mottles, over silt loam subsoil with significant orange and grey mottles
Ferrer silt loam over gravel	5	Poorly	Silt loam topsoil to 30 cm with significant orange mottles, over gravels
Ferrer clay loam	51	Poorly	Clay loam topsoil to 30cm with moderate grey mottles, over silt loam subsoil with strong gleying

Table 5. Brief descriptions of the Ferrer soils.

General Physical Properties

The physical characteristics of the sampled soil are very similar to those of the Riwaka soil (Table 6). Bulk density is moderate with values up to 1.38 g/cm^3 in the subsoil. Saturated soil hydraulic conductivity is low with the subsoil reaching as low as 4 mm/h^{-1}. Readily available water content is 134 mm in the top 1m of the profile. This is the highest level found in the sampled soils.

General Chemical Properties

Chemically these soils have moderate/low fertility (Table 6). In the sampled soil, pH is quite acidic with an average value of 5.5 throughout the profile. Potassium, calcium and magnesium are low, especially in the subsoil. All other values of the sampled soil are within the desired range. Compared to other soils in the region these soils have favourable fertility.

Soil properties of the Ferrer silt loam			
	Topsoil	Subsoil	
		Upper	Lower
Bulk density (g/cm^3)	0.99-1.13	1.30	1.38
Saturated hydraulic conductivity ($mm\ h^{-1}$)	41-370	23	4-29
Readily available water (mm)			
to 50cm depth	55		
to 100cm depth	134		
pH	5.4-5.5	5.3	5.5-5.7
CEC (me/100g)	18-22	13	14-16
P retention (%)	36.5-40.2	33.6	34.0-36.7
Base saturation (%)	36-55	25	35-47
K (me/100g)	0.1-0.61	0.15	0.03-0.05
Ca (me/100g)	5.2-8.6	2.8	3.9-4.8
Mg (me/100g)	0.83-1.74	0.35	0.77-2.69
Na (me/100g)	0.07-0.16	0.4	0.06-0.13

Table 6. Physical and chemical properties of the Ferrer soil.

Soil Profile

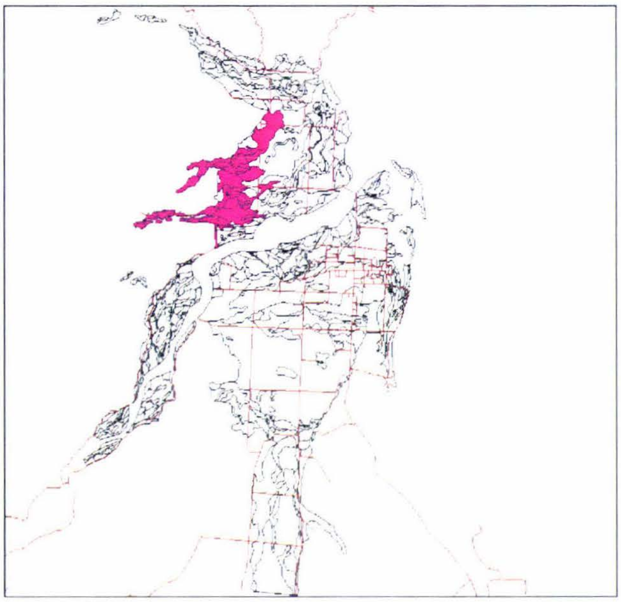
A brief typical profile of the Ferrer soil (see appendix A2 for a full description), the Ferrer silt loam located between SH60 and Swamp road, map reference NZMS 260-N27 091137, is:

A *0-32 cm*
greyish brown silt loam; firm; small blocky breaking to medium crumb structure; few distinct pale brown mottles; indistinct boundary

Bg 32-*100 cm*
light yellowish brown silt loam; firm; moderate blocky breaking to medium nut structure; abundant prominent brown and strong brown mottles:

100+ cm sand and gravels increase with depth until the water table is reached at 2 m.

UMUKURI SOIL SERIES (UM)



Key Points

- Alluvial material from the Brooklyn and Little Sydney Valleys
- Predominantly excessively to well drained
- Umukuri medium sand and Umukuri fine sand over silt dominate
- Alluvium of somewhat between that of the Riwaka and Sherry soils
- Differs from Riwaka soils with a significant amount of granitic material but also with proportions of other rock particles
- Differs from Sherry soil by less proportion of granite

Detailed Description

Umukuri soils dominate some 341 ha from Brooklyn settlement, north along the base of the hills. The parent material is derived from alluvial deposits from the Brooklyn and Little Sydney Streams. The geological makeup of the alluvium lies somewhat between that of the Riwaka and Sherry soils, principally with a significant amount of granitic material but also with proportions of other rock particles. Chittenden *et al.* (1966) grouped these soils into the Sherry, indicating that they are closely related to this soil unit. There are 13 different map units displayed, ranging from coarse sand through to silt loams (Table 7). The dominant types are the medium sandy loam (61 ha) and silt loam (60 ha).

Type	ha	Drainage	Brief description
Umukuri gravelly sand	1	Excessively	Coarse gravelly sand topsoil to 25 cm, over coarse sand
Umukuri coarse sand	8	Excessively	Coarse sand topsoil to 30 cm, over sand
Umukuri medium sand	61	Excessively	Medium sand topsoil to 25 cm, over medium sand subsoil
Umukuri medium sand over gravel	12	Excessively	Medium sand topsoil to 25 cm over gravel
Umukuri medium sand over silt	11	Well	Medium sand topsoil to 35cm, over silt
Umukuri sandy loam	22	Well	Sandy loam topsoil to 20 cm over sand
Umukuri sandy loam over gravel	5	Well	Sandy loam topsoil to 35 cm over gravel
Umukuri fine sand over sandy loam	3	Well	Fine sand topsoil to 30 cm over sandy loam
Umukuri fine sand over silt	61	Well	Fine sand topsoil to 30cm over silt
Umukuri fine sandy loam	31	Well	Fine sandy loam topsoil to 25cm, over sand
Umukuri silt loam	60	Well	Silt loam topsoil to 35cm, over sandy loam subsoil
Umukuri silt loam over clay	6	Moderately well	Silt loam topsoil to 30cm, over clay subsoil with moderate orange mottles at depth
Umukuri clay loam	10	Moderately well	Clay loam topsoil to 30cm, over silt loam subsoil

Table 7 Brief descriptions of the of the Umukuri soils.

General Physical Properties

These soils are physically suitable for many land uses. Bulk density in the sampled soil range between 1.25 and 1.36 g/cm^3 (Table 8). Saturated soil hydraulic conductivity is on the slightly excessive end of the scale ranging between 84 and 454 mm/h^{-1}. Water holding capacity in the top one metre is 114 mm for plant readily available water, and 136 mm for total plant available water.

General Chemical Properties

The sampled soil, is chemically similar to the Riwaka soils (Table 8) with a pH ranging between 6.1 and 6.4. Olsen P is significantly higher though with values up to 71µgP/g in the topsoil. All other major chemical properties are similar to the Riwaka soils, except cation exchange capacity, which is slightly lower.

Soil properties of the Umukuri medium sandy loam			
	Topsoil	Subsoil	
		Upper	Lower
Bulk density (g/cm^3)	1.31-1.34	1.25-1.27	1.36
Saturated hydraulic conductivity (mm h^{-1})	84-120	390	454
Readily available water (mm) to 50cm depth to 100cm depth	 65 114		
pH	6.4-6.5	6.3	6.1-6.4
CEC (me/100g)	12-17	7-13	3-6
P retention (%)	12.1-20.4	16.9-21.2	7.0-15.1
Base saturation (%)	69-77	49-61	55-61
K (me/100g)	0.49-0.82	0.12-0.30	0.03-0.08
Ca (me/100g)	5.3-8.8	2.3-4.7	1.5-2.5
Mg (me/100g)	2.48-3.21	1.20-2.69	0.33-0.45
Na (me/100g)	0.02-0.03	0.01-0.04	0.02-0.04

Table 8. Physical and chemical properties of the Umukuri soil.

Soil Profile

A typical brief profile of the Umukuri medium sandy loam soil (see appendix A3 for a full description) at the HortResearch site on Old Mill Rd, map reference NZMS 260 N26 079123, is:

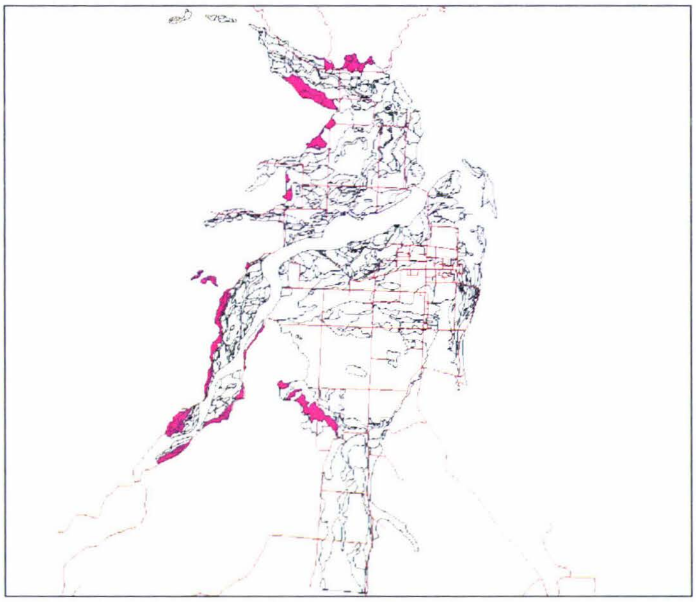
A *0-22 cm*
dark greyish brown sandy loam; very friable; weakly developed, fine and medium nut structure; indistinct boundary

B/C$_1$ *22-52 cm*
brown sand/sandy loam; loose, single grained structure; diffuse wavy boundary

uA 52-70 cm
greyish brown silt loam; friable; moderately developed, fine nut structure; distinct boundary

C$_2$ *65-100 cm*
dark yellowish brown silt loam; very friable; moderate fine and medium nut structure; grading down to layered sands.

SHERRY SOIL SERIES (SH)



Key Points

- Alluvial soils of predominantly granitic material
- Found on fans leading down to the Riwaka soil
- Predominantly excessively drained but also imperfectly drained in places
- Differ from the Umukuri and Riwaka soils by increased amount of granite in parent material

Detailed Description

Sherry soils are located on fans at the base of granite slopes. They are formed from primarily granitic alluvium of small side catchments, and are located on sites up the Motueka, Riwaka and Moutere Valleys. These soils are not regularly flooded as they are slightly elevated above the Riwaka soils on fans. The soil profile commonly has coarse granitic sand subsoil. Sixteen different types are mapped totalling 213 ha, with the majority being variations of sandy textured soil types (Table 9). Sherry sandy loam dominates with 43 ha. Sherry silt loam is common in the Riwaka Valley.

Type	ha	Drainage	Brief description
Sherry coarse sand	13	Excessively	Coarse sand topsoil to 20cm, over coarse sand
Sherry coarse sand over silt	4	Excessively	Coarse sand topsoil to 20cm, over silt
Sherry medium sand	8	Excessively	Medium sand topsoil to 20cm over sand
Sherry coarse sandy loam over sand	1	Well	Coarse sandy loam to 20cm over sand
Sherry medium sandy loam	17	Well	Medium sandy loam topsoil to 20cm over sandy loam
Sherry medium sandy loam over sand	5	Well	Medium sandy loam topsoil to 20cm over sand
Sherry medium sandy loam over silt	19	Well	Medium sandy loam topsoil to 20cm over silt
Sherry medium sandy loam over clay	3	Well	Medium sandy loam topsoil to 20cm over clay
Sherry sandy loam	43	Well	Sandy loam topsoil to 20cm, over sand
Sherry fine sand	17	Well	Fine sand topsoil to 20cm over medium sand
Sherry fine sand over silt	2	Well	Fine sand topsoil to 20cm over silt
Sherry silt loam	13	Moderately well	Silt loam topsoil to 30cm, over sandy loam subsoil
Sherry silt loam over gravel	3	Moderately well	Silt loam topsoil to 30cm, over gravelsl
Sherry silt loam over clay loam	41	Moderately well	Silt loam topsoil to 30cm over clay loam
Sherry medium sandy loam over silt wet	4	Imperfectly	Medium sandy loam topsoil to 20cm over silt with common grey mottles in subsoil
Sherry silt loam - wet	5	Imperfectly	Silt loam topsoil to 30cm, over sandy loam subsoil with grey mottles

Table 9. Descriptions of the Sherry soils.

General Physical Properties

The physical characteristics of these soils are generally favourable (Table 10). Bulk density is within the desired range with values ranging from 1.03 to 1.46 g/cm^3 in the sampled soil. Saturated soil hydraulic conductivity is high in the top 50 cm of the profile with values ranging from 124 to 3816 mm/h^{-1}. Values decrease in the subsoil, slowing to 47 mm/h^{-1} at depth. Readily and total available water contents in the top one metre are moderate with 84 mm and 107 mm respectively. Most of this water is in the lower part of the profile.

General Chemical Properties

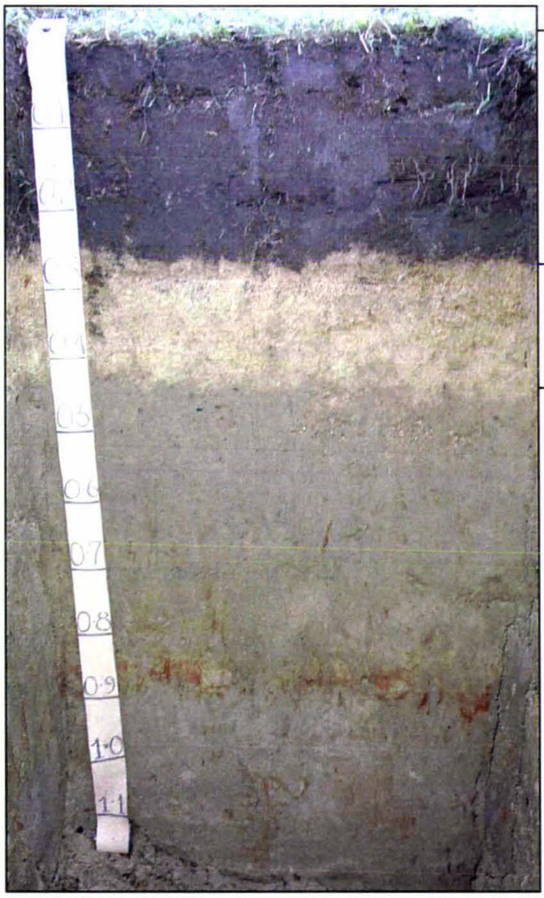
The natural fertility of the sampled soil is very low (Table 10). The pH proportionally increased from 5.5 in the topsoil to 5.9 in the lower subsoil. The levels of all major elements are below the desired levels. Deficiencies in trace elements such as boron, magnesium and cobalt have also been recorded (Chittenden *et al.*, 1966).

Soil properties of the Sherry medium sandy loam			
	Topsoil	Subsoil	
		Upper	Lower
Bulk density (g/cm^3)	1.03-1.33	1.37-1.46	1.46
Saturated hydraulic conductivity (mm h^{-1})	124-161	70-3816	47
Readily available water (mm) to 50cm depth to 100cm depth	 40 84		
pH	5.4-5.5	5.6-5.7	5.7-5.9
CEC (me/100g)	10-15	2-4	3-4
P retention (%)	18.9-23.0	6.4-17.3	10.6-20.2
Base saturation (%)	24-37	13-21	6
K (me/100g)	0.06-0.15	0.02	0.01
Ca (me/100g)	2.0-3.8	0.2-0.4	0.1-0.2
Mg (me/100g)	0.26-0.68	0.05-0.07	0.01-0.02
Na (me/100g)	0.06-0.08	0.02	0.03-0.04

Table 10. Physical and chemical properties of the Sherry soil.

Soil Profile

A typical brief profile description of the Sherry soil (see appendix A4 for a full description), the Sherry medium sandy loam, found off the Motueka River West Bank Road, map reference NZMS 260 044066 is:

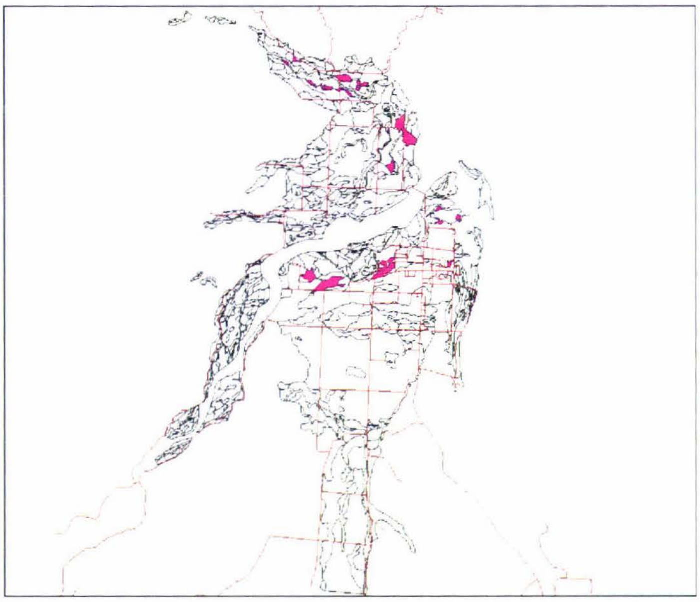


Ap *0-27 cm*
dark brown medium sandy loam; friable; weak fine and medium nut structure; sharp undulating boundary

C *27-43 cm*
pale yellow coarse sand; loose; very weak singular grain structure; few, dark reddish brown mottles; sharp undulating boundary.

2Bw or 2C *43-100 cm*–
light grey coarse sand; loose; weak soil strength; weak blocky structure; few dark reddish brown mottles; few small pebbles.

Maori Soil Series (MA)



Key Points

- Altered soil by pre European Maori
- Gravelly and sandy topsoil, with unaltered subsoils
- Located within Riwaka soils
- Highly variable imported gravel content, with charcoal
- Excessively to well drained soil

Detailed Description

Maori people significantly altered the soil by the addition of sand/gravels and burnt vegetation, causing the variability of the soil unit is quite high. Evidence of their activity can still be seen in the form of garden walls and terraces, structures for the storage and wintering of crops, and discoveries of digging implements such as ko (Challis, 1978). These alterations are still evident and thus provide sufficient modification (especially the topsoil) to justify their own soil series. These soils are typically located within the Riwaka soil series (mainly in silt loams) on slightly elevated sites away from regular flooding and swampy areas. Five different soil types are identified in the map, ranging from gravelly sandy loam through to sandy loam.

The total area of these soils amounts to 92 ha, with the Maori gravelly sandy loam dominating with 28 ha. All these soils have topsoil of the same texture as the soil name to a depth of 30 cm, then typically a silt loam subsoil below this. Gravels are also common at depth in these soils.

General Physical Properties

The physical properties of this soil are similar to the Riwaka soil, especially in the subsoil. The topsoil however, has a greater concentration of sand and or gravels, which affects the physical properties of the soil substantially. Saturated hydraulic conductivity of the soil is increased throughout the topsoil, as well as bulk density in the top 10 cm. Water retention in this soil though is reduced due to the increase in sands and gravels.

General Chemical Properties

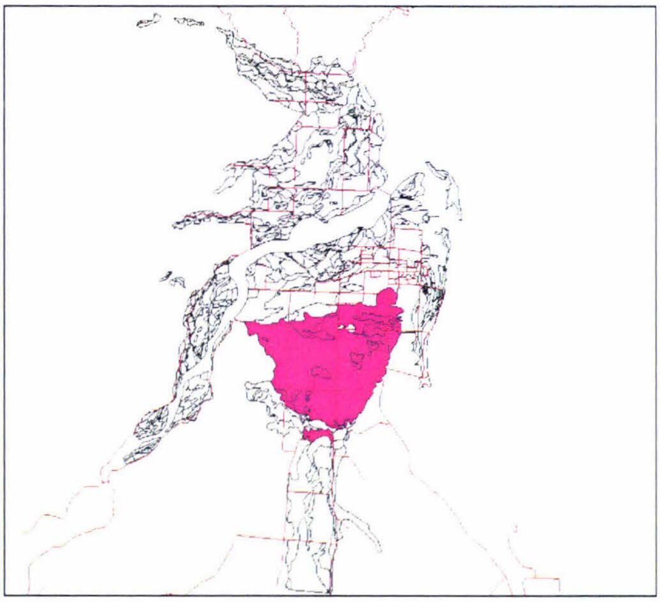
Initially these soils were chemically superior to many of the adjacent soils (Rigg & Bruce, 1923). The chemical difference today is less pronounced as the processes that produced this soil (burning vegetation) have not been continued, and the fertility has consequently slowly reverted (Challis, 1976). Chemical properties of these soils are very similar to Riwaka series.

Soil Profile

A typical profile of the Maori gravelly sandy loam, extracted from Challis (1978) is:

Ap	*34 cm*	*Dark brown friable, gravelly sandy loam with coarse sand and gravel*
B	*51 cm*	*Dull yellowish-brown, compact, sticky sandy loam*
C	*on*	*Layers of light brown sandy silt, and fine, medium and coarse sand*

HAU SOIL SERIES (HA)



Key Points

- Stony and gravelly unit south of Motueka township
- Similar parent rocks to the Riwaka soils
- Likely to be Ohakean (late last glacial) in age
- Well to excessively well drained

Detailed description

The Hau soils form a clearly defined soil unit, which is found south-west of Motueka township, covering 794 ha making this the second most dominant unit on the map. The soil unit very gently slopes towards the north where it meets with Riwaka soils. There are only two map units differentiated in this soil series, being the Hau stony sandy loam (639 ha), and Hau Gravelly sandy loam (155 ha). The soils are very stony, often with stones and gravels to the surface (figure 3). These gravels and stones consist predominately of greywacke, argillite, quartzite, limestone, granite, and basic rocks (Chittenden *et al.*, 1966), which is similar to the Riwaka soils. The age of these soils though is much greater, more likely to be of late last glacial (Ohakean) age.

Figure 3. A ploughed paddock of the Hau soil (near the corner of Chamberlain and College Streets)

General Physical Properties

The physical characteristics of this soil are dominated by the presence of gravels. Saturated hydraulic conductivity of the soil is therefore high, and water holding capacity of the soil is low.

General Chemical Properties

Natural fertility of this soil is low, with moderate deficiencies of phosphorus, and significant deficiencies of calcium and potassium (Chittenden *et al.*, 1966). Other features such as CEC and P retention are likely to also be low due to the gravels.

Soil Profile

A typical profile of the Hau stony sandy loam is:

A	*22 cm*	*black stony sandy loam; very friable; weak fine/very fine crumb structure; abundant non/weakly weathered stones; distinct boundary.*
Bw	*60 cm*	*yellowish brown stony sandy loam; friable/firm; very weak fine crumb structure; abundant non/weakly weathered stones.*
C	*on*	*weakly weathered sandy gravels.*

MOTUEKA SOIL SERIES (MO)

Key Points

- New soil series formerly included in Riwaka soils.
- Stony or gravelly to the soil surface (generally non arable)
- Excessively to well drained
- Generally found close to a watercourse

Detailed Description

These soils are formed from the same parent rocks that make up the Riwaka soils, and were included in Riwaka series. Due to their excessive stony and gravelly profiles, and being non arable they are here classified into an individual series. The area that these soil types cover is reasonably small, amounting to 135 ha, and is commonly located close to the Motueka or Riwaka Rivers.

There are four soil types differentiated within this soil series, being the Motueka stony sand (58 ha), Motueka gravelly sand (43 ha), Motueka stony sandy loam (8 ha), and Motueka gravelly sandy loam (26 ha). The key difference between these types is the size of the rocks, as well as the amount of loamy material within the soil matrix. The stones and gravels usually occur within 20 cm of the soil surface, however, often within a soil map unit there is considerable variation, with small pockets of deeper soil being common.

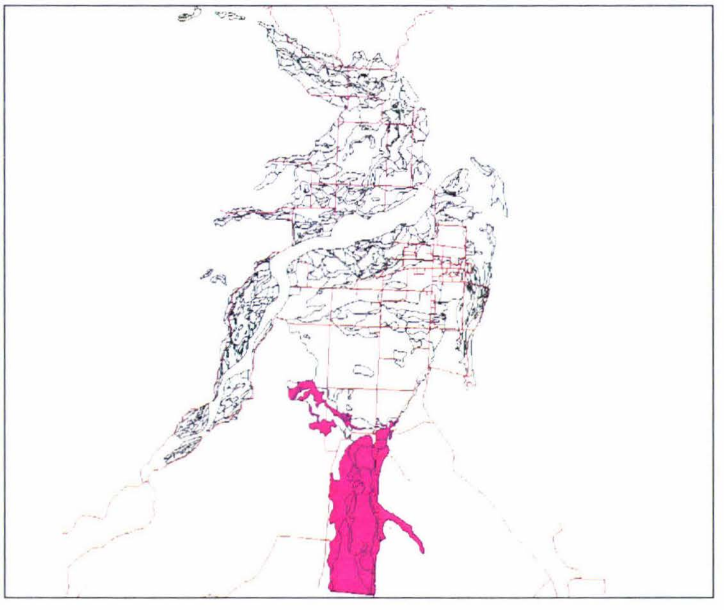
General Physical Properties

The physical properties of these soils are very similar to those of the Hau soil. Saturated hydraulic conductivity of the soil is high, and water holding capacity of is low.

General Chemical Properties

The chemical properties of these soils are similar to the Riwaka soil. The CEC and P retention levels however are lower due to the increase in gravels.

BRAEBURN SOIL SERIES (BR)



Key Points

- Located in the Moutere Valley
- Imperfectly drained to poorly drained soils

Detailed Description

The Braeburn soils are formed on poorly resorted alluvium from the Moutere Gravels, and occupy the entire Moutere Valley. They occupy 591 ha of the study area. Soil types present are sandy loam (17 ha), silt loam (295 ha) clay loam (203 ha) and silt loam – wet (39 ha) and are generally imperfectly to poorly drained. The texture of the profiles is fairly consistant, however the sandy loam soils generally have a silt or clay subsoil (at about 30cm). The sandy loams occupy the area adjacent to the Moutere River in a ribbon like fashion, whereas the silt loams are found at the foot of the steeper slopes. The clay loams occupy the area in between these two soils, and are the most dominant soil type in the area.

General Physical Properties

The physical properties of these soils are poor. These soils have poor drainage and thus a low saturated hydraulic conductivity. Often there is also an impeding iron pan, causing a perched water table, which is typically found at about 60 cm depth. Bulk densities of these soils are high.

General Physical Properties

These soils have a very low natural fertility and are deficient in a number of elements. Levels of phosphorus and potassium are at very low levels, calcium is at low levels and trace elements are deficient in boron, magnesium, copper and cobalt (Chittenden *et al.*, 1966).

Soil Profile

A brief profile of the Braeburn sandy loam soil extracted from Chittenden *et al.*, (1966) is:

Ap1	*9 in. (23 cm)*	*dark grey sandy loam, friable, strongly developed medium nutty and fine granular structure;*
Ap2	*6 in. (15 cm)*	*dull yellowish grey silt loam with veins of topsoil, strongly developed coarse nutty structure;*
Bg1	*8 in. (20 cm)*	*greyish yellow silt loam with pale brown mottling, weakly developed medium blocky structure;*
Cg	*on*	*clay.*

LAND USE

Apples, kiwifruit and hops dominate the productive soils in the study area (Table 11). Apples are the most dominant land use and occupy 1489 ha (30%) of the study area. The area in kiwifruit and hops are also substantial with 583 ha (12%) and 256 ha (5%) respectively. Pasture is also substantial with 1419 ha (28%), but much of this is the poorer soil types with gravelly or drainage limitations. Motueka township and other buildings occupy 1002 ha (20%) of the study area.

	Ferrer Soils		*Hau Soils*		*Motueka Soils*		*Maori Soils*		*Braeburn Soils*		*Tahunanui Sands*		*Umukuri Soils*		*Riwaka Soils*		*Sherry Soils*		**TOTAL**	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
Hops	17	6	0	0	3	2	10	11	0	0	0	0	32	11	150	8	6	3	**218**	**5**
Apples	48	17	305	39	48	38	23	27	171	33	8	5	96	34	517	28	45	21	**1261**	**30**
Pears	0	0	0	0	0	0	0	0	0	0	0	0	17	6	19	1	4	2	**40**	**1**
Kiwifruit	10	4	131	17	11	9	17	19	1	0	8	5	32	11	260	14	29	14	**499**	**12**
Pasture	136	47	160	20	46	36	9	11	314	60	8	4	52	18	382	21	91	43	**1207**	**28**
Currents	1	0	12	2	2	2	3	3	0	0	0	0	11	4	58	3	0	0	**87**	**2**
Grapes	0	0	14	2	6	5	2	3	0	0	0	0	0	0	27	1	0	0	**49**	**1**
Citrus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**	**0**
Research	0	0	0	0	0	0	1	2	0	0	0	0	12	4	18	1	0	0	**31**	**1**
Olives	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**0**
Buildings	11	4	31	4	9	7	13	15	21	4	7	4	26	9	128	7	21	10	**267**	**6**
Town-Motueka	47	16	125	16	0	0	5	6	0	0	137	77	0	0	236	13	0	0	**550**	**14**
Roses	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0	0	**14**	**0**
Raspberries	0	0	1	0	1	0	0	0	0	0	0	0	0	0	5	0	0	0	**7**	**0**
Market Garden	1	0	0	0	0	0	3	3	0	0	6	4	0	0	14	1	13	6	**37**	**1**
Trees	11	4	2	0	2	2	0	0	18	3	4	2	8	3	21	1	3	2	**69**	**2**
Gravel Extraction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	**5**	**0**
TOTAL ha*	**291**		**782**		**128**		**86**		**526**		**178**		**287**		**1855**		**213**		***4345***	

Table 11. Land uses and distribution on differing soil series in the Motueka area.

The Tahunanui sands are not currently intensively used for productive uses as they are mainly occupied by Motueka township. Poor water holding capacities restrict any current potential land use utilisation on the remaining unoccupied soils.

The land uses on the Riwaka soils cover almost the entire range found within the study area. Apples (28%), pasture (21%), kiwifruit (14%) and hops (8%) dominate the

* Total hectares vary from the values mentioned in the soil descriptions due to roads being excluded from the land use map in this analysis.

productive land uses. A significant proportion of these soils are also covered by Motueka township and rural buildings (20%). The majority of the hops grown in the study area are on these soils.

Pasture is by far the most dominant land use covering almost 50% on the Ferrer soils, however, there are also significant areas in apples (48 ha). Apple production will be problematic on this soil unless the water table is permanently lowered. The Motueka Township occupies 47 ha of these soils.

The Umukuri soils are currently intensively used with a great diversity of land uses. Apple and pear orchards are the most dominant (96 ha or 40% of the study area), but there are also significant areas of kiwifruit, hops (32 ha each) and pasture (52 ha).

The dominant land use on the Sherry soil types is pasture with 43% of the area covered. Other land uses with significant areas are apples (21%) and kiwifruit (14%). Market gardens are a significant land use with 13ha of the total 37 ha in the study area being on this series. Most of the market gardens in the study area are the located on the finer textured Sherry soils.

The area occupied by the Maori soils is relatively small, amounting to only 86 ha. The main land uses on these soil types are apples, kiwifruit and hops. There is a higher proportion of kiwifruit on this soil unit, possibly due to the enhanced drainage.

Despite the stony nature of Hau soils and chemical fertility limitations they are still intensively used for apple production, with 305 ha or 39% of the soil in this land use. Kiwifuit is also grown, with 131 ha in this crop. Other crops such as hops are absent. Provided adequate irrigation is available (especially during the initial establishment of the trees) it has been proven that viable and economic orchards can be grown on these soils.

On the Motueka floodplain the Motueka soils are predominantly used for apple production, however, up the Motueka valley much of these soil units are in pasture. In total there are 48 ha in apples, 46 ha in pasture and 11 ha in kiwifruit. There is also a small area of these soil units in other crops such as hops, blackcurrant, and raspberries.

The dominant land use on the Braeburn soil is pasture covering 60% of the 314 ha. The only other productive use on these soils is apple production, which cover 33% of the area. Again apple production is likely to be hampered by drainage unless water table permanently lowered. Kiwifruit are not present, probably primarily due to the poor drainage of the soil.

CONCLUSION

The land covered by the Motueka soil map is intensively occupied by highly valued horticultural land uses. The major crop grown is apples, with significant areas of kiwifruit and hops. There is also a substantial area of pasture, with 28% of the study area occupied by this land use.

The soils are naturally moderately fertile and provide adequate levels of required factors for the current horticultural crops. This along with the favourable climate makes the area very suitable for productive land uses.

This report summarises the features of the main soils, including new data on the Riwaka, Umukuri and Ferrer soils collected during this study. The Riwaka and Umukuri soils are the most highly valued soils covered in the map.

New soil series are introduced to better reflect the soil properties and land use potential of the Motueka soil map. These were the Ferrer and Motueka soil, which were previously incorporated into the Riwaka series.

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A1 Detailed Profile Description – Riwaka soil

Riwaka silt loam 11/6/03

Location: in apple and pear orchard two hundred meters along and fifty meters north of Green Lane (opposite the north-eastern corner of the Motueka airport). Pit in rows between trees.

Map reference: NSMS 260-N27 101099.

Vegetation: apple and pear orchard. Clover and rye grass between rows, with herbicide spray strip under rows of trees. Sprinkler irrigation to each tree. Orchard established, 20 years old.

Landform: flat alluvial terrace of Motueka River, no longer flooded. Parent material is a composite of alluvium from the Motueka River catchment.

Representative Soil Profile Description:

Ap1 0-10 cm	olive brown (2.5Y 4/4) silt loam; friable/firm nutty structure, compacted by orchard activities; strong soil strength; plastic, sticky; many small roots and worms; indistinct boundary.
Ap2 10-38 cm	bight olive brown (2.5Y 5/4) silt loam; firm blocky/nut structure; plastic, sticky; strong soil strength; few medium and fine roots; indistinct boundary.
Bw1 38-70 cm	light olive brown (2.5Y 5/3) silt loam texture; blocky/nutty structure; plastic, sticky; strong soil strength; very few medium/fine roots; few small stones throughout the horizon; few, fine, faint light yellowish brown (2.5Y 6/3) and brownish yellow (10YR 6/6) mottles near base of horizon; indistinct boundary.
Bw2 70-110 cm	olive brown (2.5Y 4/3) fine sandy loam; fine to medium nutty structure; plastic, sticky; strong soil strength; few (10%) small (<5 cm) granite, fine grained igneous, greywacke, quartzite gravels in profile; old root channels in horizon; few, coarse, distinct light grey (2.5Y 7/2) mottles; indistinct boundary.
110 cm+	same as above but 50% gravels.

A2 Detailed Profile Description – Ferrer soil

Ferrer silt loam 12/6/03

Location:	West of Riwaka Township, 1000m from State Highway 60, midway to Swamp Road.
Map reference:	NSMS 260-N26 091137.
Vegetation:	Pasture of ryegrass and clover, which is in good condition. Kiwifruit growing in an orchard fifty meters to the west.
Landform:	Generally flat topography with slight mounds and dips due to fluvial formation. Extensive drainage in surrounding area.

Representative Soil Profile Description:

Ap	0-32 cm	dark greyish brown (2.5Y 4/2) silt loam; firm; small blocky breaking to medium crumb structure; plastic, sticky; many small roots; few distinct pale brown (10YR 6/3) mottles, increasing towards base, especially on ped faces; distinct boundary.
Bg1	32-51 cm	light yellowish brown (2.5Y 6/3) silt loam; firm; moderate/medium blocky with medium crumb structure; plastic, slightly sticky; many fine roots and root cannels; abundant (40%) faint, strong brown (7.5YR 5/6) and strong brown (7.5YR 4/6) mottles; common strong brown (7.5YR 5/6) coatings on peds; gradational boundary.
Bg2	51-93 cm	light yellowish brown (2.5Y 6/3) silt loam; firm; moderate, medium blocky, breaking to medium crumb structure; plastic, slightly sticky; abundant (40%) distinct strong brown (7.5YR 5/6) and strong brown (7.5YR 4/6) mottles; many (20%) profuse prominent iron coatings, dark reddish brown (5Y 3/3) on ped faces, also 10% light brownish grey (2.5Y 6/2) on ped faces; many fine root channels coated with dark olive brown (5Y 3/2); gradational boundary.
Bg3	93-120 cm	light olive brown (2.5Y 5/3) silt loam, sand increasing at the base of the horizon; firm; weak, medium blocky structure; plastic, slightly sticky; moderate (20%) distinct strong brown (7.5YR 5/6) and strong brown (7.5YR 4/6) mottles; few (20%) distinct very dusky red (2.5YR 2.5/3) iron coatings on ped face; many fine root channels with dark olive brown (5Y 3/2) coatings; gradational boundary.
	120-200 cm	(auger observation) sand increases with depth until coarse sand at depth; very wet at 200 cm, water table reached.

A3 Detailed Profile Description – Umukuri soil

Umukuri medium sandy loam	12/6/03
Location:	Old Mill Road, two hundred meters east of HortReseach buildings, 40 meters south of road, one hundred meters north of Brooklyn Stream.
Map Reference:	NZMS 260-N26 079123.
Vegetation:	Currently in pasture with rye grass, Yorkshire fog, yarrow and dandelion. Previously been used as an orchard.
Landform:	Flat topography. Brooklyn Stream is stop banked, with the streambed higher than the land outside the stop banks.
Ap 0-23 cm	(Ap1 0-3 cm, Ap2 3-23 cm) very dark greyish brown (2.5Y 3/2) 0-3 cm, dark olive brown (2.5Y 3/3) 3-23 cm medium sandy loam; friable; medium to fine nut structure; non plastic, sticky; many medium to fine roots and earthworms; indistinct boundary.
Bw 23-28 cm	light olive brown (2.5Y 5/6) fine sandy loam; friable; fine to medium crumb structure; non plastic, sticky; few fine roots; few pieces of charcoal; indistinct boundary.
uA 28-36 cm	(buried soil) olive brown (2.5Y 4/4) fine sandy loam; friable; fine crumb structure; non plastic, sticky; few fine roots; few pieces of charcoal; diffuse wavy boundary.
B/C1 36-61 cm	light grey (2.5Y 6/2) (C), light olive brown (2.5Y 5/3) (B) fine sandy loam; very friable; very weak fine crumb structure; non plastic, non sticky; few fine roots and pieces of charcoal; diffuse wavy boundary.
B/C2 61-78 cm	light olive brown (2.5Y 5/4) medium sandy loam; friable; weak medium/small crumb structure; non plastic, slightly sticky; many small roots; diffuse wavy boundary.
C1 78-101 cm	greyish brown (2.5Y 5/2) medium loamy sand; loose/very friable; very weak/no small nutty breaking to granular structure; non plastic and non sticky; few small roots; sand increases in coarseness with depth; blackish band 98-101 cm of heavy mineral concentrations; bedded coarse sand and grit (5 cm) bands; diffuse wavy boundary.
B/C3 101-115 cm	similar to 61-78 cm but only few small roots.
C2 115-130 cm+	same as 78-101 cm, no black bands evident.

A4 Detailed Profile Description –Sherry soil

Sherry medium sandy loam 10/06/03

Location: 100m below gravel pit on Motueka River West Bank Road, 10m south from fence, 30m from stream.

***Map reference*:** NSMS 260-N27 044066

Vegetation: low producing pasture, brown top, ryegrass, moss, minor clover, plantain, Yorkshire fog and other low fertility grasses. Gorse next to stream. Little/no fertiliser added in previous ten years.

Landform: alluvial fan form small tributary to the Motueka River, southeast facing slope 5-7 degrees. Large granite boulders nearby.

Representative Soil Profile Description:

Ap 0-26 cm dark brown (7.5YR 3/2) medium sandy loam; friable; non plastic, non sticky; weak fine and medium nut breaking to moderate-coarse crumb structure; many fine roots; sharp undulating boundary.

C 26-47 cm pale yellow (2.5Y 7/3) coarse sand; loose; non plastic, non sticky; very weak singular grain structure; few, fine roots; few, fine, faint, dark reddish brown (5Y 3/4) mottles; sharp undulating boundary.

2Bw 47-92 cm light yellowish brown (2.5Y 6/3) medium sandy loam; friable; non plastic, non sticky; weak soil strength; weak medium crumb structure; no roots; few, fine, faint dark reddish brown (5Y 3/4) mottles increasing to abundant, medium, distinct 85-92 cm; discontinuous band of coarser sand and fine pebbles at 52 cm, approximately 1 cm thick; charcoal in this horizon, possibly from European clearance; gradational boundary.

2C 92-110 cm+ light grey (2.5Y 7/2) coarse sand; loose; non plastic, non sticky; weak soil strength; weak, coarse, blocky structure; few coarse, strong, dark reddish brown 5Y (3/4) mottles; few small pebbles.

CHAPTER EIGHT

Discussion and Conclusion

8.1 Validity of the Original Soil Map

An assessment of the validity of the original soil map was established during fieldwork, where over five hundred auger observations within the study area were undertaken. This method was in reverse to how a typical soil map is produced, where the description of the soils is typically followed by a legend, and lastly a map is created. The original soil map provided a reasonably accurate portrayal of the distribution of the soils within its extent, with three key limitations – texture, drainage and parent material.

8.1.1 Texture

The map portrayed textural distinctions of the soil types fairly rigorously. This was more evident where there was a significant change in textural type, e.g. from a silt to a stony sandy loam. At locations where textural changes were not abrupt, but rather merged into each other, the soil boundaries were expectedly less accurately defined. This is due to the nature under which these soils were formed, an alluvial floodplain. Under this process deposited alluvium is typically laid down with a decreasing size in particle density as the distance from the river increases. Soil units are therefore not clearly defined due to this process, but rather portray the most suitable location to place the soil boundary. This was most evident during the fieldwork where silt loams were adjacent to fine sandy loams, especially in the Riwaka series. Both gradational and rapid changes in texture are to be expected where soil parent materials are laid down by fluvial processes.

8.1.2 Drainage

It became evident during fieldwork to validate the original map that drainage classes were not consistently distinguished in the determination of soil classes. While the poorly drained soils that show considerable gleying are identified as wet soils within the individual soil series, soils that exhibit less pronounced signs of gleying, e.g. imperfectly drained, are often included in series where most types are free draining. This was found where the newly classified Ferrer series was extracted from the Riwaka series. This may possibly be due to the lack of understanding of the significance that drainage classes have on some land uses (e.g. kiwifruits susceptibility to wet roots), and the fact that the surveyors would have been using screw augers, which makes features such as mottles a great deal more difficult to identify.

8.1.3 Parent material

The distinction of parent materials is the single biggest factor for the classification of soils into the defined soil series on the paper map. This was a major assistance to this study as the distinctions between soils of differing parent materials were difficult to determine from auger observations, especially between the Riwaka and Umukuri soils. Differentiating the source of parent materials during the fieldwork was complicated due to the reasonably flat nature of the study area, but also because of the intensive horticultural land use. Landscape modification and densely planted trees made it difficult to obtain a comprehensive perspective of the surrounding area, and thus the possible distribution of parent materials.

8.2 Anomalies

The newly digitised soil map provided an accurate portrayal of the discovered paper soil map. There were though a few anomalies, but a reason for most could be ascertained.

The most evident irregularity was the position of the Motueka River, which is probably due to changes that the river has taken in the fifty years or so since the map was produced. The most common areas where this occurred were at the river bends, where the river had either cut into, or out of a corner. The other rivers in the study area (Riwaka and Moutere) did not show as significant discrepancies, and were positioned accurately. Stop-banking may also have an effect on the positioning of the river.

The position of the soils up the smaller side valleys seemed to be incorrect, especially when the map was draped over aerial photos or a topographic map. The main areas where this occurred were up the Little Sydney and Brooklyn Valleys. Often the soils appeared to occurr on the sides of valleys where they clearly were not meant to be. It was commonly obvious where the soils were meant to fit onto the landscape, as the shape of the soil polygon matched up with distinct areas on the aerial photos. Therefore there was either some error in the initial positioning of the soils on the paper map, or when the digital soil map was rectified.

8.3 Modification to the Soil Map

There was generally little need to modify the soil map, and the changes that were made were not significant. Changes either involved a modification to the polygon by altering the vertices and/or moving the entire polygon. Database modifications were also made usually to reclassify existing soil units.

8.3.1 Polygon modification

The biggest modification made to the digitised map was the clipping of the digitised map to the exclude the areas inside the existing stop banks of the Motueka River. This was done as it was concluded that the area inside the stop banks is extremely vulnerable to flooding, and therefore little use for productive uses and have probably been modified. The stop banks were defined from 1:50,000 topographic data obtained from the Tasman District Council, but were also modified to ensure that they reflected a scale of 1:20,000. Clipping the soil map to the stop banks also resolved the discrepancy between where the river flowed when the map was produced, and its current course.

Other modifications made were the repositioning of the soil units up the Little Sydney and Brooklyn Valleys. This did not commonly evolve a substantial shift in the polygon, but rather a minor transfer.

8.3.2 Database modification

The Riwaka soil unit was relatively significantly altered. On the paper map the Riwaka soils covered the entire spectrum of soil drainage and textural classes. This study removed all the 'wet' and 'stony and gravelly' Riwaka soils from the current Riwaka series and created two new soil series for these soils.

A new soil series was created to encompass all the poorly and imperfectly drained soils previously included in Riwaka series. This new series was named the Ferrer series. The series name 'Ferrer' was selected due to the nearby location of Ferrer Creek depicted on the NZMS 260 N26 map sheet. A new series was deemed necessary as these soil types have significantly different pedological and land use characteristics than the rest of the Riwaka series.

The previously classified Riwaka stony and gravelly soil types were reclassified into a new soil series, the Motueka soil series. The name 'Motueka' was selected as this soil is predominantly found alongside the Motueka River, and near Motueka township. This reclassification was necessary as these soil types were considerably different than the Riwaka series. The Motueka soil types frequently have gravels within the upper 20 cm of the profile, and are therefore classified as stony soils. These soils could not be included into the Hau series as the age difference is too great.

8.4 Accuracy of the Produced Map

Unmapped Ferrer soils are present as inclusions within polygons identified as Riwaka soils, particularly close to polygons now mapped as Ferrer soils. The significance of these inclusions is thought to be small. Although they display the characteristics of a poorly drained soil (mottles), it has been proven that with the extensive drainage that has occurred on this unit, drainage has been effective. There are currently substantial areas of successful apple and kiwifruit orchards, and hop gardens on this soil, which further indicate that drainage is no longer a significant factor. Because of the scope of this study it was also deemed that attempting to resurvey these areas could not be sufficiently completed within the timeframe allocated.

8.4.1 Limitations of scale

The scale of the map produced (1:20,000) is not sufficient for planning by individual growers, investing in land, or planning land management changes. A map at a scale of 1:5,000 is recommended for such activities. This is recommended as the fluvial pattern of the area covered by the map causes rapid changes within small distances. The cost of developing a map at this scale is small compared to the investment undertaken by land purchase.

It is also noted that not all land uses in the district are well matched to soil. There is considerable scope for changes in land uses.

8.5 Conclusion

The produced and ground truthed map is now a useful asset for parties interested on the soils of Motueka. This modern up to date 1:20,000 map now has a legend and descriptions. An accompanying soil survey report has also been produced.

Through extensive ground truthing it is concluded that the original paper map was an accurate portrayal of the distribution of soils, based on texture and parent material. However, new series are here introduced to take account of diverse drainage classes.

Nine soil series are used to describe and differentiate the soils. These are the previously classified Riwaka, Umukuri, Sherry, Maori, Braeburn and Tahunanui series, as well as the newly introduced Ferrer and Motueka series. There are 74 different soil types within these soil series, all of which are meaningful in a practical sense. The previously existing map was generalised where necessary to make it more suitable for practical use. Some of the original type and phase descriptions on the paper map are here updated to modern terminology to avoid confusion.

The four soils selected for further physical and chemical analysis (the Riwaka, Umukuri, Sherry and Ferrer soils) provided useful results. These soils have been selected due to their extensive area, current intensive use and physical and chemical fertility. The Umukuri has the most favourable physical properties, with desired values for saturated soil hydraulic conductivity and bulk density, and moderate water holding capacity. Surprisingly the Riwaka soil is found to have a high bulk density (reaching 1.59 in the subsoil), slow saturated hydraulic conductivity (down to 3 mm/h) and the lowest readily available water content (59 mm in the top 1m). The Riwaka soil however, is the most chemically fertile soil. All soils generally have low CEC, low exchangeable potassium and low phosphorus retention, making them only moderately chemically fertile. The Sherry soil displayed the poorest chemical characteristics with most factors tested below desired levels.

A land evaluation rated the suitability of kiwifruit, blackcurrants and hops production on the Riwaka silt loam, Umukuri medium sandy loam, Sherry medium sandy loam and the Ferrer silt loam. The Umukuri soil is rated the best soil with a total average rating of 1.73 for all crops. The Riwaka and Ferrer soils rate similarly with values of approximately 2, while the Sherry soil rates the lowest with values between 2.14 and 2.18. The rating exercise shows that the study area is very well suited to these crops.

CHAPTER 9

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9.1 Personal Communication

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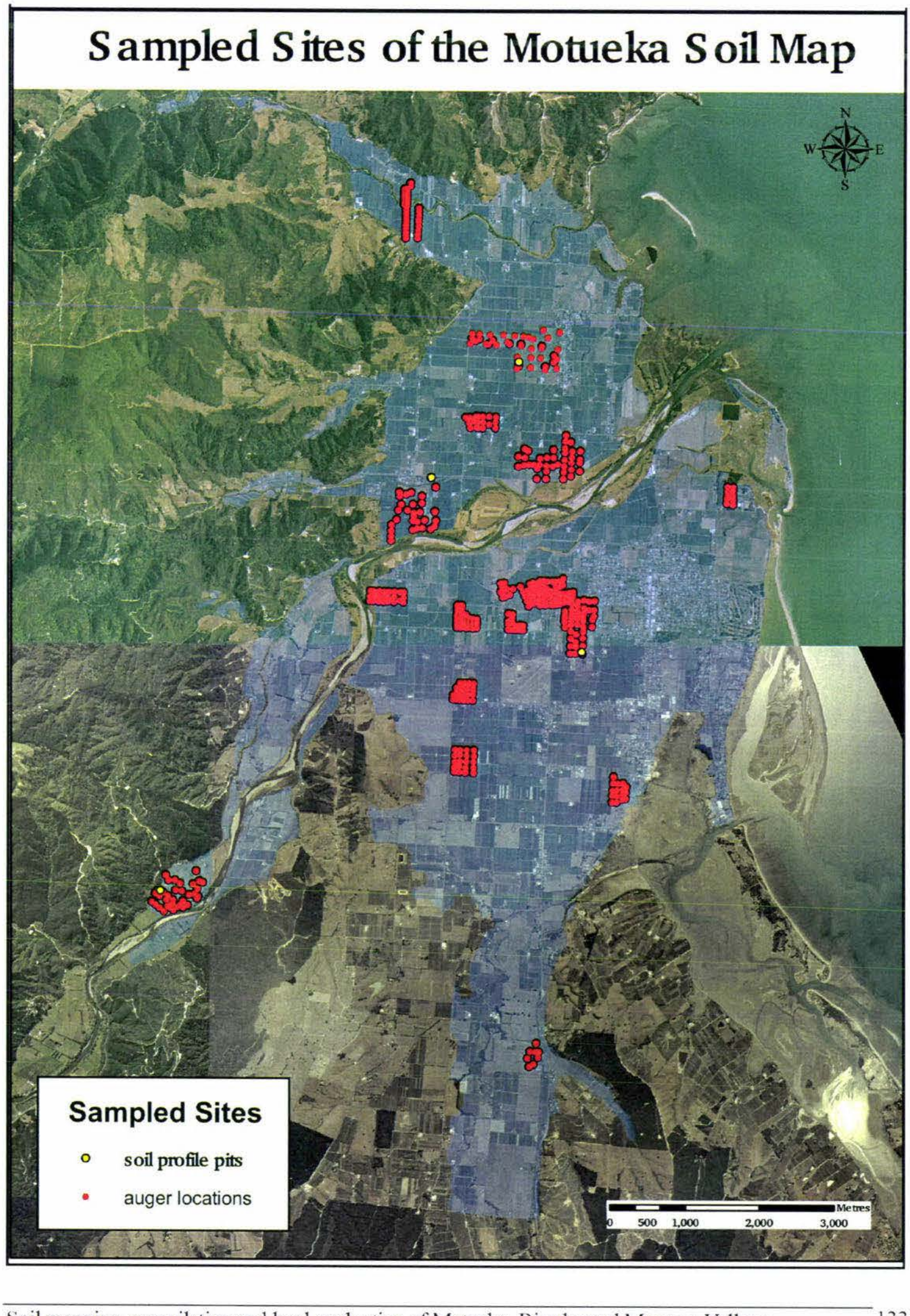
APPENDICES

A1 - Auger Observations and Pit locations



A2 - Individual Soil Bulk Density Results

Riwaka	Sample				
	A	*B*	*C*	*D*	*Average*
1-6 cm					
Dried Soil & Container (g)	123.31	139.42	131.56	117.4	
Container Weight (g)	37.5	41.98	37.64	36.8	
Soil Weight (g)	85.81	97.44	93.92	80.6	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	0.94	1.07	1.03	0.89	0.98
12-17 cm					
Dried Soil & Container (g)	159.79	174.09	171.63	172.4	
Container Weight (g)	38.75	37.77	41.91	42.72	
Soil Weight (g)	121.04	136.32	129.72	129.68	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.33	1.50	1.43	1.43	1.42
40-45 cm					
Dried Soil & Container (g)	180.29	185.5	185.19	184.51	
Container Weight (g)	38.02	41.59	42.12	37.37	
Soil Weight (g)	142.27	143.91	143.07	147.14	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.57	1.58	1.57	1.62	1.59
75-80 cm					
Dried Soil & Container (g)	189.54	185.41	182.24	182.57	
Container Weight (g)	42.91	42.2	37.74	37.91	
Soil Weight (g)	146.63	143.21	144.5	144.66	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.61	1.58	1.59	1.59	1.59

Umukuri	Sample				
	A	*B*	*C*	*D*	*Average*
4-9 cm					
Dried Soil & Container (g)	157.07	156.59	147.44	169.84	
Container Weight (g)	39.33	37.4	37.37	42.07	
Soil Weight (g)	117.74	119.19	110.07	127.77	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.30	1.31	1.21	1.41	1.31
23-28					
Dried Soil & Container (g)	163.69	160.83	161.21	159.4	
Container Weight (g)	42	37.96	37.74	38.87	
Soil Weight (g)	121.69	122.87	123.47	120.53	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.34	1.35	1.36	1.33	1.34
40-45 cm					
Dried Soil & Container (g)	153.08	161.24	153.49	169.66	
Container Weight (g)	43.2	44.6	41.38	52.23	
Soil Weight (g)	109.88	116.64	112.11	117.43	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.21	1.28	1.23	1.29	1.25
65-70 cm					
Dried Soil & Container (g)	164.18	171.68	163.51	158.59	
Container Weight (g)	48.73	56.95	45.77	45.52	
Soil Weight (g)	115.45	114.73	117.74	113.07	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.27	1.26	1.30	1.24	1.27
78-101 cm					
Dried Soil & Container (g)	266.87	266.44	261.86	221.91	
Container Weight (g)	142.79	141.1	139.65	100.22	
Soil Weight (g)	124.08	125.34	122.21	121.69	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.37	1.38	1.34	1.34	1.36

Sherry	Sample				
	A	*B*	*C*	*D*	*Average*
1-6 cm					
Dried Soil & Container (g)	130.09	129.3	136.06	134.67	
Container Weight (g)	38.77	38.39	38.79	38.5	
Soil Weight (g)	91.32	90.91	97.27	96.17	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g cm^3)	1.00	1.00	1.07	1.06	1.03
10-15 cm					
Dried Soil & Container (g)	160.19	163.91	164.12	161.03	
Container Weight (g)	37.7	42.94	42.97	42.99	
Soil Weight (g)	122.49	120.97	121.15	118.04	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g cm^3)	1.35	1.33	1.33	1.30	1.33
26-31 cm					
Dried Soil & Container (g)	183.26	176.36	172.42		
Container Weight (g)	57.67	49.6	52.3		
Soil Weight (g)	125.59	126.76	120.12		
Container Volume (cm^3)	90.89	90.89	90.89		
Bulk Density (g cm^3)	1.38	1.39	1.32		1.37
47-52 cm					
Dried Soil & Container (g)	185.13	184.27	177.71	191.2	
Container Weight (g)	51.75	51.86	46.07	57.81	
Soil Weight (g)	133.38	132.41	131.64	133.39	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g cm^3)	1.47	1.46	1.45	1.47	1.46
70-75 cm					
Dried Soil & Container (g)	180.74	176.9	183.72	186.38	
Container Weight (g)	48.04	44.6	51.83	53.5	
Soil Weight (g)	132.7	132.3	131.89	132.88	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g cm^3)	1.46	1.46	1.45	1.46	1.46

Ferrer	Sample				
	A	*B*	*C*	*D*	*Average*
2-7 cm					
Dried Soil & Container (g)	130.03	131.95	130.54	129.41	
Container Weight (g)	42.05	41.91	37.67	42.08	
Soil Weight (g)	87.98	90.04	92.87	87.33	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g cm^3)	0.97	0.99	1.02	0.96	0.99
15-20 cm					
Dried Soil & Container (g)	148.1	139.64	142.65	141.1	
Container Weight (g)	42.23	38.37	41.8	37.1	
Soil Weight (g)	105.87	101.27	100.85	104	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.16	1.11	1.11	1.14	1.13
35-40 cm					
Dried Soil & Container (g)	225.08	263.85	255.5	257.46	
Container Weight (g)	104.18	141.84	138.26	144.16	
Soil Weight (g)	120.9	122.01	117.24	113.3	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.33	1.34	1.29	1.25	1.30
60-65 cm					
Dried Soil & Container (g)	170.27	265.63	267.33	233.94	
Container Weight (g)	44.79	141.59	144.2	105.56	
Soil Weight (g)	125.48	124.04	123.13	128.38	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.38	1.36	1.35	1.41	1.38
100-105 cm					
Dried Soil & Container (g)	172.01	162.85	168.43	170.81	
Container Weight (g)	45.6	37.89	43.36	47.34	
Soil Weight (g)	126.41	124.96	125.07	123.47	
Container Volume (cm^3)	90.89	90.89	90.89	90.89	
Bulk Density (g/cm^3)	1.39	1.37	1.38	1.36	1.38

A3 – Raw and Calculated Data for Saturated Soil Hydraulic Conductivity

Riwaka Soil

Raw data (ml)

		TIME (MINUTES)											
DEPTH		**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**1230**	
1-11 cm	*A*	2000	3000	2000	2000	4000	2000	800	525	475	400	-	
	B	2000	2000	880	860	1040	850	1350	1900	1000	1200	-	
	C	4000	2000	870	600	1430	1000	750	470	320	280	-	
12-22 cm	*A*	375	190	130	100	75	55	50	45	45	45	-	
	B	200	210	170	125	100	80	100	75	75	70	-	
	C	80	80	75	50	50	40	40	30	30	25	-	
46-50 cm	*A*	15	15	20	10	10	10	20	10	10	10	20	
	B	40	45	30	20	40	40	40	30	15	15	80	
	C	180	170	125	90	80	70	60	45	50	55	-	
75-85 cm	*A*	0	5	5	5	5	5	5	5	5	5	10	
	B	40	40	40	30	30	30	35	25	10	10	25	
	C	0	5	0	0	5	10	5	5	2	2	0	

Saturated hydraulic conductivity mm h^{-1}

		TIME (MINUTES)											
DEPTH		**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**1230**	**Average**
1-11 cm	*A*	954	1431	954	954	1908	954	382	250	227	191	-	
	B	954	954	420	410	496	405	644	906	477	572	-	
	C	1908	954	415	286	682	477	358	224	153	134	-	**299**
12-22 cm	*A*	179	91	62	48	36	26	24	21	21	21	-	
	B	95	100	81	60	48	38	48	36	36	33	-	
	C	38	38	36	24	24	19	19	14	14	12	-	**22**
46-50 cm	*A*	7	7	10	5	5	5	10	5	5	5	0	
	B	19	21	14	10	19	19	19	14	7	7	1	
	C	86	81	60	43	38	33	29	21	24	26	-	**13**
75-85 cm	*A*	0	2	2	2	2	2	2	2	2	2	0	
	B	19	19	19	14	14	14	17	12	5	5	0	
	C	0	2	0	0	2	5	2	2	1	1	0	**3**

Umukuri Soil

Raw data (ml)						
		TIME (MINUTES)				
DEPTH		15	30	60	90	Average
4-14 cm	A	70	90	150	150	
	B	190	190	350	330	
	C	160	160	280	275	160
23-33 cm	A	60	90	180	180	
	B	50	100	210	200	
	C	75	90	160	150	177
40-50 cm	A	250	375	775	800	
	B	190	300	575	575	
	C	470	550	1065	1075	817
65-75	A	315	400	775	790	
	B	760	475	1425	1475	
	C	240	300	600	590	952

Saturated hydraulic conductivity mm h^{-1}						
		TIME (MINUTES)				
DEPTH		15	30	60	90	Average
4-14 cm	A	67	86	72	72	
	B	181	181	167	157	
	C	153	153	134	131	**120**
23-33 cm	A	57	86	86	86	
	B	48	95	100	95	
	C	72	86	76	72	**84**
40-50 cm	A	239	358	370	382	
	B	181	286	274	274	
	C	448	525	508	513	**390**
65-75	A	301	382	370	377	
	B	725	453	680	704	
	C	229	286	286	281	**454**

Sherry Soil

Raw data (ml)										
		TIME (MINUTES)								
DEPTH		10	25	40	55	70	100	130	160	190
0-10 cm	A	350	305	265	240	205	350	310	270	270
	B	80	145	165	170	150	275	260	235	240
	C	150	210	215	205	185	325	300	270	270
10-20 cm	A	200	290	300	275	250	430	375	330	375
	B	150	260	250	245	220	370	340	290	325
	C	110	220	230	230	210	370	340	320	310
26-36 cm	A	-	-	-	4000	4000	-	-	-	-
	B	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-
47-57 cm	A	140	155	145	120	100	175	150	140	140
	B	210	240	200	150	140	220	220	200	200
	C	180	125	100	90	80	120	120	110	100
70-80 cm	A	350	125	100	80	70	100	100	95	100
	B	200	145	125	95	80	125	120	105	120
	C	180	160	125	75	60	90	90	80	75

Saturated hydraulic conductivity mm h^{-1}											
		TIME (MINUTES)									
DEPTH		10	25	40	55	70	100	130	160	190	Average
0-10 cm	A	501	291	253	229	196	167	148	129	129	
	B	114	138	157	162	143	131	124	112	114	
	C	215	200	205	196	177	155	143	129	129	**124**
10-20 cm	A	286	277	286	262	239	205	179	157	179	
	B	215	248	239	234	210	177	162	138	155	
	C	157	210	219	219	200	177	162	153	148	**161**
26-36 cm	A	-	-	-	3816	3816	-	-	-	-	
	B	-	-	-	-	-	-	-	-	-	
	C	-	-	-	-	-	-	-	-	-	**3816**
47-57 cm	A	200	148	138	114	95	83	72	67	67	
	B	301	229	191	143	134	105	105	95	95	
	C	258	119	95	86	76	57	57	52	48	**70**
70-80 cm	A	501	119	95	76	67	48	48	45	48	
	B	286	138	119	91	76	60	57	50	57	
	C	258	153	119	72	57	43	43	38	36	**47**

Ferrer Soil

Raw data (ml)

TIME (MINUTES)

DEPTH		**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**1300**
2-12 cm	*A*	290	500	380	310	250	225	180	190	180	-
	B	300	570	570	560	1300*	1750	1500	1600	1550	-
	C	350	1330	1800	1075	1350	1500	2700*	1000	600	-
15-25 cm	*A*	250	375	225	170	130	110	75	25	70	-
	B	-	-	-	-	-	-	-	-	-	-
	C	800	500	290	225	200	150	120	120	100	-
35-45 cm	*A*	50	90	70	50	45	40	25	25	25	-
	B	110	210	175	130	120	100	80	75	70	-
	C	110	175	125	90	75	70	50	50	50	-
60-70	*A*	30	65	50	35	30	25	25	25	20	-
	B	600	570	480	310	250	200	120	110	100	-
100-110	*A*	50	190	50	50	40	25	20	20	15	90
	B	10	15	15	10	5	5	5	5	2	0

** Worm fell out of core into container*

Saturated hydraulic conductivity mm h^{-1}

TIME (MINUTES)

DEPTH		**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**1230**	**Average**
2-12 cm	*A*	138	239	181	148	119	107	86	91	86	-	
	B	143	272	272	267	620	835	716	763	739	-	
	C	167	634	859	513	644	716	1288	477	286	-	**370**
15-25 cm	*A*	119	179	107	81	62	52	36	12	33	-	
	B	-	-	-	-	-	-	-	-	-	-	
	C	382	239	138	107	95	72	57	57	48	-	**41**
35-45 cm	*A*	24	43	33	24	21	19	12	12	12	-	
	B	52	100	83	62	57	48	38	36	33	-	
	C	52	83	60	43	36	33	24	24	24	-	**23**
60-70	*A*	14	31	24	17	14	12	12	12	10	-	
	B	286	272	229	148	119	95	57	52	48	-	**29**
100-110	*A*	24	91	24	24	19	12	10	10	7	1	
	B	5	7	7	5	2	2	2	2	1	0	**4**

A4 - Raw and Calculated Pressure Plate Data

Riwaka raw pressure plates

0.1 bar	Sample	wet 18/7	dry 22/7	gm's H2O	% H20	Container	Volumetric	
1-3 cm	A	77.3	60.16	17.14	28.49	25.3	0.48	48
	B	78.73	50.95	27.78	54.52	21.04	0.91	91
12-14 cm	A	87.7	74.12	13.58	18.32	20.2	0.36	36
	B	84.52	71.3	13.22	18.54	21.02	0.37	37
40-42 cm	A	86.97	74.45	12.52	16.82	21.22	0.37	37
	B	91.93	79.1	12.83	16.22	24.26	0.37	37
75-78 cm	A	96.95	84.59	12.36	14.61	24.94	0.33	33
	B	81.92	71.42	10.5	14.70	19.91	0.32	32

1 bar		wet 1/8	dry 4/8	gm's H2O	% H20	Container		
1-3 cm	A	67.18	53.24	13.94	26.18	21.08	0.42	42
	B	71.95	55.2	16.75	30.34	20.95	0.48	48
12-14 cm	A	99.03	85.26	13.77	16.15	25.48	0.33	33
	B	80.99	69.21	11.78	17.02	20.24	0.34	34
40-42 cm	A	102.05	88.51	13.54	15.30	25.18	0.34	34
	B	92.45	80.44	12.01	14.93	21.31	0.32	32
75-78 cm	A	94.76	82.87	11.89	14.35	20.95	0.31	31
	B	88.49	77.74	10.75	13.83	19.81	0.30	30

15 bar		wet /7	dry 4/8	gm's H2O	% H20	Container		
1-3 cm	A	33.06	28.51	4.55	15.96	13.42	0.30	30
12-14 cm	A	37.13	32.82	4.31	13.13	13.36	0.31	31
40-42 cm	A	33.88	30.54	3.34	10.94	13.32	0.31	31
75-78 cm	A	42.96	38.56	4.4	11.41	13.26	0.28	28

Riwaka calculated pressure plates

Horizon	Horizon depth	Horizon Depth (cm)	Sample	Water content (%v/v) at tensions (kPa)			Available Water (Tensions in kPa)			
							Sample (%)		Horizon (mm)	
				10	100	1500	Readily	Total	Readily	Total
	0-12 cm	12	A	48	43					
	0-12 cm	12	B	91	48	30	24	40	29	48
	12-40 cm	28	A	36	33					
	12-40 cm	28	B	37	34	315	3	5	9	14
	40-75 cm	35	A	37	34					
	40-75 cm	35	B	37	32	31	4	6	15	23
	75-100 cm	25	A	33	31					
	75-100 cm	25	B	32	30	28	3	5	7	13
TOTAL									**59**	**98**

Umukuri raw pressure plates

0.1 bar	Sample	wet 30/6	dry 3/7	gm's H2O	% H20	Container	VOLUMETRIC	
4-6 cm	A	77.24	65.29	11.95	18.30	20.1	0.35	34.64
	B	87.9	74.95	12.95	17.28	20.91	0.31	31.39
23-25 cm	A	64.08	56.87	7.21	12.68	23.99	0.29	29.38
	B	86.24	75.52	10.72	14.19	25.16	0.29	28.52
40-42 cm	A	87	75.13	11.87	15.80	23.95	0.29	28.99
	B	82.74	70.73	12.01	16.98	24.36	0.32	32.38
65-67 cm	A	85.15	75.19	9.96	13.25	25.45	0.25	25.43
	B	80.17	69.56	10.61	15.25	21.67	0.28	28.14
78-80 cm	A	61.91	58.77	3.14	5.34	22.81	0.12	11.88
	B	60.44	56.63	3.81	6.73	18.52	0.14	13.60

1 bar		wet 10/7	dry 11/7	gm's H2O	% H20	Container	VOLUMETRIC	
4-6 cm	A	67.08	60.27	6.81	11.30	19.93	0.22	22.11
	B	81	73.27	7.73	10.55	25.45	0.21	21.18
23-25 cm	A	81.27	74.34	6.93	9.32	20.12	0.17	17.13
	B	190.93	183.67	7.26	3.95	127.51	0.17	17.32
40-42 cm	A	185.88	178.62	7.26	4.06	127.77	0.18	17.85
	B	176.2	170.2	6	3.53	122.21	0.16	15.63
65-67 cm	A	176.55	172.01	4.54	2.64	123.86	0.12	11.97
	B	134.74	130.62	4.12	3.15	88.12	0.12	12.31
78-80 cm	A	127.74	125.97	1.77	1.41	88.48	0.06	6.42
	B	160.51	158.81	1.7	1.07	121.2	0.06	6.15

15 bar		wet 10/7	dry 11/7	gm's H2O	% H20	Container	VOLUMETRIC	
4-6 cm	A	28.01	26.21	1.8	6.87	13.35	0.18	18.34
23-25 cm	A	23.75	22.22	1.53	6.89	9.05	0.16	15.57
40-42 cm	A	23.76	22.29	1.47	6.59	9.01	0.14	13.84
65-67 cm	A	23.93	22.77	1.16	5.09	9.28	0.11	10.92
78-80 cm	A	36.08	35.26	0.82	2.33	13.33	0.05	5.09

Umukuri calculated pressure plates

Horizon	Horizon depth	Horizon Depth (cm)	Sample	Water content (%v/v) at tensions (kPa)			Available Water (Tensions in kPa)			
							Sample (%)		*Horizon (mm)*	
				10	*100*	*1500*	*Readily*	*Total*	*Readily*	*Total*
	0-23 cm	23	A	34.6	22.1					
	0-23 cm	23	B	31.4	21.2	18.3	11.4	14.7	26.2	33.8
	23-40 cm	17	A	29.4	17.1					
	23-40 cm	17	B	28.5	17.3	15.6	11.7	13.4	19.9	22.8
	40-65 cm	25	A	29.0	17.8					
	40-65 cm	25	B	32.4	15.6	13.8	13.9	16.8	34.9	42.1
	65-78 cm	13	A	25.4	12.0					
	65-78 cm	13	B	28.1	12.3	10.9	14.6	15.9	19.0	20.6
	78-100 cm	22	A	11.9	6.4					
	78-100 cm	22	B	13.6	6.1	5.1	6.5	7.7	14.2	16.8
TOTAL									**114.2**	**136.1**

Sherry raw pressure plates

0.1 bar	Sample	wet 30/6	dry 3/7	gm's H2O	% H20	Container	Volumetric	
1-3 cm	A	74.3	59.74	14.56	24.37	25.49	0.44	44
	B	84.09	70	14.09	20.13	25.37	0.33	33
10-12 cm	A	88.21	78.36	9.85	12.57	25.41	0.25	25
	B	80.71	70.77	9.94	14.05	21.05	0.27	27
26-28 cm	A	87.92	85.62	2.3	2.69	29.97	0.06	6
	B	79.01	77.46	1.55	2.00	36.27	0.05	5
47-49 cm	A	89.59	80.26	9.33	11.62	25.62	0.25	25
	B	78.48	70.36	8.12	11.54	20.13	0.24	24
70-72 cm	A	90.97	80	10.97	13.71	21.64	0.27	27
	B	89.97	78.92	11.05	14.00	21.1	0.28	28

1 bar		wet 10/7	dry 11/7	gm's H2O	% H20	Container	Volumetric	
1-3 cm	A	72.03	63.8	8.23	12.90	21.4	0.20	20
	B	67.23	60.24	6.99	11.60	25.34	0.21	21
10-12 cm	A	79.21	73.51	5.7	7.75	21.54	0.15	15
	B	74.62	69.27	5.35	7.72	20.94	0.15	15
26-28 cm	A	66.33	65.22	1.11	1.70	21.36	0.03	3
	B	70.87	69.79	1.08	1.55	24.08	0.03	3
47-49 cm	A	80.31	74.17	6.14	8.28	20.04	0.17	17
	B	82.07	75.99	6.08	8.00	19.91	0.16	16
70-72 cm	A	86.95	79.46	7.49	9.43	20.99	0.19	19
	B	82.49	75.06	7.43	9.90	20.27	0.20	20

15 bar		wet 10/7	dry 11/7	gm's H2O	% H20	Container	VOLUMETRIC	
1-3 cm	A	19.07	17.66	1.41	7.98	8.95	0.17	17
10-12 cm	A	32.02	30.31	1.71	5.64	13.38	0.13	13
26-28 cm	A	27.75	27.38	0.37	1.35	9.11	0.03	3
47-49 cm	A	30.74	29.03	1.71	5.89	9.2	0.13	13
70-72 cm	A	33.66	31.59	2.07	6.55	13.27	0.16	16

Sherry calculated pressure plates

Horizon	Horizon depth	Horizon Depth (cm)	Water content (%v/v) at tensions (kPa)			Available Water (Tensions in kPa)			
						Sample (%)		*Horizon (mm)*	
			10	*100*	*1500*	*Readily*	*Total*	*Readily*	*Total*
	0-10 cm	10	43.8	20.0					
	0-10 cm	10	32.5	20.6	16.7	17.8	21.5	17.8	21.5
	10-26 cm	16	24.7	14.6					
	10-26 cm	16	26.6	14.7	13.4	11.0	12.2	17.6	19.6
	26-47 cm	21	5.7	3.5					
	26-47 cm	21	5.2	3.2	2.8	2.1	2.6	4.3	5.5
	47-70 cm	23	24.9	16.6					
	47-70 cm	23	23.6	15.8	12.6	8.1	11.7	18.6	26.9
	70-100 cm	30	27.4	18.7					
	70-100 cm	30	27.9	19.8	16.5	8.4	11.2	25.3	33.5
TOTAL								**84**	**107**

Ferrer raw pressure plates

0.1 bar	Sample	wet 18/7	dry 22/7	gm's H2O	% H20	Container	Volumetric	
2-5 cm	A	89.16	68.25	20.91	30.64	21.01	0.44	44
	B	68.97	50.05	18.92	37.80	21.1	0.65	65
15-17 cm	A	87.36	70.36	17	24.16	20.9	0.39	39
	B	85.67	68.92	16.75	24.30	21.19	0.40	40
35-37 cm	A	78.98	65.44	13.54	20.69	22.96	0.41	41
	B	74.77	61.75	13.02	21.09	22.61	0.43	43
60-62 cm	A	78.5	65.1	13.4	20.58	22.76	0.44	44
	B	77.37	63.6	13.77	21.65	18.29	0.42	42
100-102 cm	A	73.16	59.22	13.94	23.54	18.51	0.47	47
	B	78.5	64.41	14.09	21.88	22.87	0.47	47

1 bar		wet 1/8	dry 4/8	gm's H2O	% H20	Container	Volumetric	
2-5 cm	A	73.71	59.31	14.4	24.28	21.75	0.38	38
	B	73.09	56.65	16.44	29.02	19.62	0.44	44
15-17 cm	A	74.51	61.53	12.98	21.10	19.7	0.35	35
	B	77.01	63.5	13.51	21.28	19.63	0.35	35
35-37 cm	A	79.55	66.82	12.73	19.05	22.74	0.38	38
	B	68.11	56.69	11.42	20.14	18.64	0.39	39
60-62 cm	A	78.93	65.66	13.27	20.21	18.99	0.39	39
	B	78.34	65.28	13.06	20.01	19.15	0.39	39
100-102 cm	A	69.9	57.44	12.46	21.69	18.18	0.44	44
	B	69.34	57.07	12.27	21.50	18.55	0.44	44

15 bar		wet /7	dry 4/8	gm's H2O	% H20	Container	Volumetric	
2-5 cm	A	29.66	25.27	4.39	17.37	13.23	0.36	36
15-17 cm	A	31.8	26.62	5.18	19.46	13.41	0.44	44
35-37 cm	A	29.22	25.86	3.36	12.99	13.44	0.35	35
60-62 cm	A	34.01	29.65	4.36	14.70	13.4	0.37	37
100-102 cm	A	29.44	25.82	3.62	14.02	13.28	0.40	40

Ferrer calculated pressure plates

Horizon	Horizon depth	Horizon Depth (cm)	Sample	Water content (%v/v) at tensions (kPa)			Available Water (Tensions in kPa)			
							Sample (%)		Horizon (mm)	
				10	100	1500	Readily	Total	Readily	Total
	0-15 cm	15	A	34.6	22.1					
	0-15 cm	15	B	31.4	21.2	18.3	11.4	14.7	17.1	22.0
	15-35 cm	20	A	29.4	17.1					
	15-35 cm	20	B	28.5	17.3	15.6	11.7	13.4	23.5	26.8
	35-60 cm	25	A	29.0	17.8					
	35-60 cm	25	B	32.4	15.6	13.8	13.9	16.8	34.9	42.1
	60-100 cm	40	A	25.4	12.0					
	60-100 cm	40	B	28.1	12.3	10.9	14.6	15.9	58.6	63.5
	100-120 cm	20	A	11.9	6.4					
	100-120 cm	20	B	13.6	6.1	5.1	6.5	7.7	12.9	15.3
TOTAL									**146.8**	**169.7**

A5 – Soil Chemical Analyses Results

ANALYSES:

SAMPLE	pH	Olsen P µgP/g	SO4 µgS/g	K me/100g	Ca me/100g	Mg me/100g	Na me/100g	CEC me/100g	Soil volume g/ml
Riwaka 0-10 Comp	6.3	34.3	7.8	0.39	12.4	2.06	0.07	22	0.92
Riwaka 0-10 Pit	6.4	33.8	3.3	0.54	14.3	2.29	0.06	23	0.85
Riwaka 10-38	6.4	32.9	1.8	0.23	8.7	1.36	0.07	17	1.15
Riwaka 38-70	6.3	8.6	2.5	0.04	6.3	2.52	0.05	16	1.27
Riwaka 70-110	6.4	10.5	1.8	0.06	4.8	3.61	0.07	15	1.32
Sherry 0-10 Comp	5.5	32.9	4.5	0.15	3.8	0.61	0.08	15	0.95
Sherry 0-10 Pit	5.4	24.3	3.0	0.12	3.5	0.68	0.06	12	1.00
Sherry 10-26	5.4	13.8	1.8	0.06	2.0	0.26	0.06	10	1.12
Sherry 26-47	5.6	7.6	0.8	0.02	0.4	0.07	0.02	4	1.40
Sherry 47-70	5.7	2.9	1.5	0.02	0.2	0.05	0.02	2	1.20
Sherry 70-92	5.7	2.4	1.8	0.01	0.2	0.02	0.04	4	1.19
Sherry 92-100	5.9	1.4	1.0	0.01	0.1	0.01	0.03	3	1.38
Ferrer 0-10 Comp	5.4	41.4	12.0	0.61	8.6	1.38	0.13	19	0.85
Ferrer 0-10 Pit	5.5	47.6	12.3	0.31	8.4	1.74	0.16	22	0.86
Ferrer 20-32	5.4	26.7	8.8	0.10	5.2	0.83	0.07	18	0.97
Ferrer 32-51	5.3	46.7	13.3	0.15	2.8	0.35	0.04	13	0.94
Ferrer 51-93	5.5	52.4	12.3	0.05	3.9	0.77	0.06	14	0.99
Ferrer 93-120	5.7	42.4	12.3	0.03	4.8	2.69	0.13	16	1.10
Umukuri 0-10 Comp	6.4	61.9	2.0	0.67	7.7	2.82	0.03	15	1.03
Umukuri 0-10 Pit	6.5	71.0	1.8	0.82	8.8	3.21	0.02	17	0.92
Umukuri 23-29	6.5	42.9	1.5	0.49	5.3	2.48	0.02	12	1.09
Umukuri 29-36	6.3	27.6	1.8	0.30	4.7	2.69	0.04	13	0.99
Umukuri 36-61	6.3	13.3	1.3	0.12	2.3	1.20	0.01	7	1.19
Umukuri 61-78	6.1	13.8	2.0	0.03	2.5	0.45	0.02	6	1.20
Umukuri 78-101	6.4	7.6	1.3	0.08	1.5	0.33	0.04	3	1.55

Methodologies:

'Available' phosphate and sulphate values are expressed as µg/g (air-dry). Exchangeable cations and CEC values are expressed as me/100g (air-dry).

Soil volume is a measure of the weight of air-dry soil (g) per volume (ml) and can be used to convert results to a volume basis.

'Quick Test' values are calculated using conversion factors reported in Fertiliser Recommendations for Pastures and Crops in New Zealand (1984) compiled by I S Cornforth and A G Sinclair.

Total Carbon and Total Nitrogen were determined by IR and TC detection following combustion in an induction furnace (LECO).

Organic matter was determined mathematically: OM = OC x 1.72

Base saturation and cation ratios are calculated from the analytical data.

Phosphate retention is an empirical measure of the ability of a soil to remove phosphorus rapidly from solution, a method devised by Saunders (1965).

CONVERSION TO MAF 'QUICK TEST' VALUES:						*ADDITIONAL ANALYSES:*			
SAMPLE	**P µgP/ml**	**SO4 µgS/g**	**K**	**Ca**	**Mg**	**P Retention %**	**Carbon %**	**Total Nitrogen %**	**Organic Matter %**
Riwaka 0-10 Comp	32	8	6	13	43	24.1	3.1	0.27	5.3
Riwaka 0-10 Pit	29	3	7	14	44	21.9	3.8	0.32	6.5
Riwaka 10-38	38	2	4	12	36	22.9	1.1	0.09	1.9
Riwaka 38-70	11	3	1	9	73	17.5	0.3	0.02	0.5
Riwaka 70-110	14	2	1	7	109	16.5	0.2	0.02	0.4
Sherry 0-10 Comp	31	5	2	4	13	23.0	3.4	0.26	5.9
Sherry 0-10 Pit	24	3	2	4	15	20.0	3.3	0.28	5.7
Sherry 10-26	15	2	1	3	7	18.9	2.1	0.16	3.7
Sherry 26-47	11	1	<1	1	2	6.4	0.2	0.01	0.4
Sherry 47-70	3	2	<1	<1	1	17.3	0.6	0.02	1.1
Sherry 70-92	3	2	<1	<1	1	20.2	0.6	0.03	1.0
Sherry 92-100	2	1	<1	<1	<1	10.6	0.1	0.01	0.2
Ferrer 0-10 Comp	35	12	8	8	27	39.0	4.0	0.36	6.9
Ferrer 0-10 Pit	41	12	4	8	34	36.5	4.2	0.38	7.2
Ferrer 20-32	26	9	2	6	18	40.2	2.4	0.22	4.1
Ferrer 32-51	44	13	2	3	8	33.6	0.5	0.05	0.9
Ferrer 51-93	52	12	1	4	17	34.0	0.5	0.05	0.8
Ferrer 93-120	47	12	1	6	68	36.7	0.4	0.03	0.7
Umukuri 0-10 Comp	64	2	11	9	67	18.8	1.7	0.12	3.0
Umukuri 0-10 Pit	65	2	12	9	68	12.1	2.0	0.14	3.5
Umukuri 23-29	47	2	8	7	62	20.4	0.7	0.05	1.2
Umukuri 29-36	27	2	5	5	61	21.2	0.9	0.06	1.5
Umukuri 36-61	16	1	2	3	33	16.9	0.3	0.02	0.5
Umukuri 61-78	17	2	1	4	12	15.1	0.4	0.02	0.6
Umukuri 78-101	12	1	2	3	12	7.0	0.1	0.01	0.2

BASE SATURATION CALCULATIONS:							
SAMPLE	**BASE SAT. %**	**K % of BS**	**Ca % of BS**	**Mg % of BS**	**Na % of BS**	**Mg/K RATIO**	**Ca/Mg RATIO**
Riwaka 0-10 Comp	67	1.8	55	9.2	0.3	5.2	6.0
Riwaka 0-10 Pit	73	2.3	61	9.8	0.2	4.2	6.2
Riwaka 10-38	62	1.4	52	8.2	0.4	6.0	6.4
Riwaka 38-70	54	0.3	38	15.4	0.3	58.0	2.5
Riwaka 70-110	58	0.4	32	24.4	0.5	58.9	1.3
Sherry 0-10 Comp	32	1.1	26	4.2	0.5	3.9	6.2
Sherry 0-10 Pit	37	1.1	29	5.7	0.5	5.4	5.1
Sherry 10-26	24	0.6	21	2.6	0.6	4.2	7.9
Sherry 26-47	13	0.4	10	1.5	0.4	3.6	6.5
Sherry 47-70	21	1.5	15	2.9	1.4	2.0	5.2
Sherry 70-92	6	0.3	4	0.5	1.0	1.5	8.5
Sherry 92-100	6	0.4	4	0.4	1.0	1.0	10.1
Ferrer 0-10 Comp	55	3.1	44	7.1	0.6	2.3	6.2
Ferrer 0-10 Pit	49	1.4	39	8.0	0.7	5.6	4.8
Ferrer 20-32	36	0.6	30	4.7	0.4	8.1	6.3
Ferrer 32-51	25	1.1	21	2.6	0.3	2.3	8.0
Ferrer 51-93	35	0.3	29	5.7	0.5	17.0	5.1
Ferrer 93-120	47	0.2	29	16.4	0.8	77.7	1.8
Umukuri 0-10 Comp	75	4.5	51	18.9	0.2	4.2	2.7
Umukuri 0-10 Pit	77	4.9	53	19.3	0.1	3.9	2.8
Umukuri 23-29	69	4.1	44	20.6	0.2	5.1	2.1
Umukuri 29-36	61	2.3	37	21.1	0.3	9.1	1.8
Umukuri 36-61	49	1.7	31	16.3	0.1	9.7	1.9
Umukuri 61-78	55	0.6	46	8.1	0.4	14.4	5.7
Umukuri 78-101	61	2.4	46	10.4	1.2	4.4	4.5

Massey Agriculture

A6 - **Ranking Tables for Site Properties**

Climate

Annual Rainfall (mm)	Rating		
	Kiwifruit	B-Currants	Hops
>3000	3	3	3
2500-3000	2	2	2
1250-2500	1	1	1
900-1250	2	2	2
<900	3	3	3

Annual rainfall ratings (*adapted from* Kernohan, 1983)

Mean Temperature (°C)	Rating		
	Kiwifruit	B-Currants	Hops
>16.5	4	4	4
14.5-16.4	2	2	2
12.5-14.4	1	1	1
10-12.4	3	3	3
<10	5	5	5

Annual temperature ratings (*adapted from* Kernohan, 1983)

Frost Severity (°C)	Class	Rating		
		Kiwifruit	B-Currants	Hops
<-6	Low	1	1	1
-7 to -14	Moderate	2	2	2
>-14	High	3	3	3

Frost severity and ratings (Webb and Wilson, 1995)

Annual Ground Frosts	Rating		
	Kiwifruit	B-Currants	Hops
0 - 15	1	1	1
15 - 30	2	2	2
30 - 60	3	3	3
60 - 100	4	4	4
> 100	5	5	5

Annual ground frost ratings (*adapted from* California Kiwifruit Commission, 2000)

Annual Air Frosts	Rating		
	Kiwifruit	B-Currants	Hops
0 - 5	1	1	1
5 - 10	2	2	2
10 - 20	3	3	3
30 - 40	4	4	4
> 40	5	5	5

Annual air frost ratings (*adapted from* California Kiwifruit Commission, 2000)

Sunshine Hours (October – April)	Rating		
	Kiwifruit	B-Currants	Hops
>1400	1	1	1
1300-1400	2	2	2
1200-1300	3	3	3
1100-1200	4	4	4
<1100	5	5	5

Annual sunshine hours ratings (Webb, and Wilson, 1995)

Annual Humidity (%)	Rating		
	Kiwifruit	B-Currants	Hops
> 90	1	1	1
75 - 90	2	2	2
60 - 75	3	3	3
< 60	4	4	4

Annual humidity ratings (*adapted from* Kernohan, 1983)

Annual Days of Hail	Rating		
	Kiwifruit	B-Currants	Hops
0 - 5	1	1	1
5 - 10	2	2	2
10 - 20	3	3	3
30 - 40	4	4	4
> 40	5	5	5

Annual days of hail ratings (*adapted from* Kernohan, 1983)

Annual Days of Gail Winds	Rating		
	Kiwifruit	B-Currants	Hops
0 - 5	1	1	1
5 - 10	2	1	2
10 - 20	3	2	4
30 - 40	4	3	5
> 40	5	4	6

*Annual days of hail ratings (*adapted from *Kernohan, 1983 & Sale, 1985)*

Landscape

Slope angle (degrees)	Class	Rating		
		Kiwifruit	B-Currants	Hops
0-3	Level to very gently sloping	1	1	1
4-7	Gently sloping	2	2	2
8-11	Moderately sloping	3	3	3
12-15	Moderately sloping to strongly sloping	4	4	4
16-20	Strongly sloping	5	5	5
21-25	Moderately steep	6	6	6
26-35	Steep	7	7	7

Slope classes and ratings (Webb and Wilson, 1995)

Soil Physical

Drainage Class	Rating		
	Kiwifruit	B-Currants	Hops
Well drained	1	1	1
Moderate	2	1	1
Imperfect	3	2	2
Imperfect to poor	4	3	2
Poor	5	4	3
Very poor	6	5	4

Drainage classes and ratings (*adapted from* Webb and Wilson, 1995)

PRAW (mm)	Class	Rating		
		Kiwifruit	B-Currants	Hops
>100	Very high	1	1	1
67-100	High	2	2	2
50-67	Moderately high	3	3	3
33-50	Moderate	4	4	4
17-33	Low	5	5	5
<17	Very low	6	6	6

Profile readily available water (to 1m) (*adapted from* Webb and Wilson, 1995)

Bulk Density (Mg/m^3)	Rating		
	Kiwifruit	B-Currants	Hops
>0.8	2	2	2
0.8-1.0	1	1	1
1.0-1.2	1	1	1
1-2-1.4	2	2	2
1.4-1.6	3	3	3
>1.6	5	5	5

Highest bulk density rating (to 1m) (*adapted from* Martin, 1998)

Saturated Hydraulic Conductivity (mm/h)	Class	Rating		
		Kiwifruit	B-Currants	Hops
<4	Slow	4	3	3
4-72	Moderate	2	2	2
>72	Rapid	1	1	1

Lowest saturated hydraulic conductivity (mm/h) (*adapted from* Webb and Wilson, 1995)

Stone Content (%) (0-30 cm)	Class	Rating		
		Kiwifruit	B-Currants	Hops
<5	Non-gravelly to very slightly gravelly	1	1	1
5-15	Slightly gravelly	1	2	2
15-35	Moderately gravelly	2	3	3
35-70	Very gravelly	3	4	4
>70	Extremely gravelly	4	5	5

Stone content (0-30 cm) ratings and classes (*adapted from* Webb and Wilson, 1995)

Soil Chemical

Soil pH (0-60 cm)	Rating		
	Kiwifruit	B-Currants	Hops
6.9-6.3	1	1	1
7.2-6.9 & 6.3-6.0	2	2	2
7.5-7.2 & 6.0-5.7	3	3	3
7.8-7.5 & 5.7-5.4	4	4	4
8.1-7.8 & 5.4-5.1	5	5	5
>8.1 & <5.1	6	6	6

Soil pH (20-60 cm) ratings (*adapted from* Martin, 1998)

CEC top 0-60 cm (meq./100g)	Class	Rating		
		Kiwifruit	B-Currants	Hops
>40	Very high	1	1	1
24-40	high	2	2	2
12-25	medium	3	3	3
6-12	low	4	4	4
<6	Very low	5	5	5

CEC classes and ratings in top 60 cm (*adapted from* Webb and Wilson, 1995)

Potassium (me/100g)	Rating		
	Kiwifruit	B-Currants	Hops
<0.6	3	3	3
0.6-0.8	2	2	2
0.8-1.0	1	1	1
1.0-1.2	2	2	2
>1.2	4	4	4

Potassium ratings in top 20 cm (*adapted from* Hill Laboratories, 2002)

Calcium (me/100g)	Rating		
	Kiwifruit	B-Currants	Hops
<6	3	3	3
06-08	2	2	2
08-12	1	1	1
>12	2	2	2

Calcium ratings in top 20 cm (*adapted from* Hill Laboratories, 2002)

Sodium (me/100g)	Rating		
	Kiwifruit	B-Currants	Hops
0.0-0.4	1	1	1
0.4-0.8	2	2	2
>0.8	3	3	3

Sodium ratings in top 20 cm (*adapted from* Hill Laboratories, 2002)

Magnesium (me/100g)	Rating		
	Kiwifruit	B-Currants	Hops
<1	3	2	2
1-3	1	1	1
3-5	2	2	2
>5	3	3	3

Magnesium ratings in top 20 cm (*adapted from* Hill Laboratories, 2002)

P retention within 0-20 cm (%)	Class	Rating		
		Kiwifruit	B-Currants	Hops
>85	Very high	1	1	1
60-85	high	2	2	2
30-60	medium	3	3	3
<30	low	4	4	4

P retention classes and ratings in top 20 cm *(adapted from* Webb and Wilson, 1995)

A7 - Textural Summary for Soil Units

	0-35cm	35-70	70-105	105+
Tahunanui fixed dune sand	fine sand	fine sand	fine sand	fine sand
Riwaka silt loam	silt loam	silt loam	silt loam	silt loam
Ferrer silt loam	silt loam	silt loam	silt loam	sand & gravels
Umukuri medium sandy loam	sandy loam	sand/sandy loam	silt loam	silt loam
Sherry medium sandy loam	medium sandy loam	sand/sandy loam - coarse sand	coarse sand	coarse sand
Maori gravelly sandy loam	Gravely sandy loam with coarse sand & gravel	sandy loam	sandy silt	sandy silt - fine, medium and coarse sand
Hau stony sandy loam	stony sandy loam	stony sandy loam	sandy gravels	sandy gravels
Motueka soils	similar to the Hau	“	“	“
Braeburn sandy loam soil	sandy loam	silt loam	clay	clay