ABSTRACT

The lower Wairarapa Valley was an estuary as late as 6 500 years ago. Since then sediments from the Ruamahanga and Tauherenikau Rivers have deposited large loads of sediment into the area, prograding the eastern shore and changing the system from an estuary into lakes and rivers.

The aims of this study were to investigate the late Quaternary deposits and soils of the eastern shore of Lake Wairarapa, using the information gained to look at the way in which infilling has taken place.

The surface geology and soils of the study area were mapped. The mapping units were described and defined. Some chemical tests were carried out on selected soil samples.

The order and method of infilling of the deposits are discussed.

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CHAPTER ONE: INTRODUCTION.

1.1.0 Aims and scope of study.

The primary aim of the study was to map the late Quaternary deposits on the eastern shore of Lake Wairarapa. Specifically to:

(a) Examine the history of infilling of the study area by fluvial and fluvio-lacustrine sediments, i.e. the development of deltas into the lake.

(b) Examine the chronosequence of sand dunes around the lake margin.

(c) Produce a soil map and detail land resources of the area.

Late Quaternary deposits, physiographic units and soils of the study area were mapped at a scale of 1:25 000.

When describing properties of the landscape and in particular soils, morphology, rather than detailed chemical and physical tests was used as a basis for interpretation. A few chemical analyses were carried out on soil samples however, to reveal broad trends in soil chemical properties. These were:

(1) pH in H_2O, KCl and $CaCl_2$,

(2) C%,

(3) N%,

(4) C/N ratio,

(5) inorganic, organic and total P.

1.2.0 Location and setting of the study area.

1.2.1 Location and extent of study area.

The study area lies on the eastern shore of Lake Wairarapa in southern Wairarapa Valley. Its boundaries are the lake margin in the north-west, the former Ruamahanga River channel in the south-west, Kahutara Road in the south-east and Mangatete Stream in the north-east (figure 1). These boundaries enclose an area of just over 4 100 hectares (approximately 10 150 acres).

An additional area outside the above boundaries, is the large north-east to south-west trending dune line lying just east of the study area. It was studied to complete the chronosequence of dune soils (figure 1).

1.2.2 Setting of the study area.

Wairarapa Valley is a structural depression 77km long and up to 20km wide that plunges south to Palliser Bay (Kamp and Vucetich 1982). It is bounded to the west by the Rimutaka and Tararua Ranges, and to the east by the Eastern Hills and Aorangi Mountains (figure 2). The southern end of the valley is flat and low lying (Heine 1975).

Lake Wairarapa sits at the head of a riverine and lacustrine complex which ends at Lake Onoke (Wairarapa Catchment Board A). Water discharges from Lake Onoke into Palliser Bay through an outlet in the shingle bar which separates Lake Onoke from the sea (figures 1, 2 and plate 1). When the outlet is open Lake Onoke is estuarine, tidal fluctuations to a height of 0.5m affecting up to 25km of the Ruamahanga River. At times this regular backflow carries salt water into Lake Wairarapa as evidenced by the presence of salt water dependent plants in places around the lake (Wairarapa Catchment Board 1985).

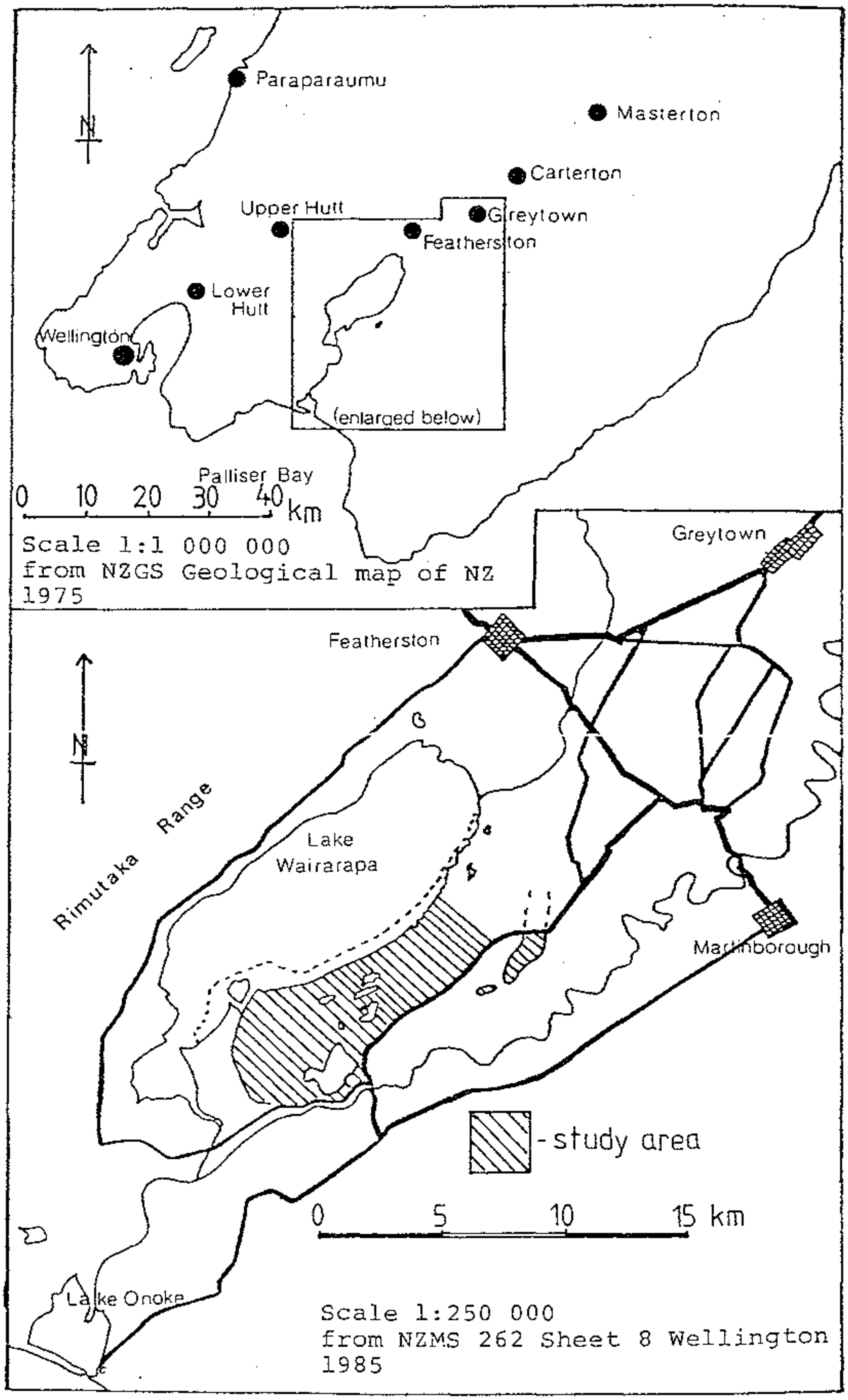


Figure 1 Location of the study area.

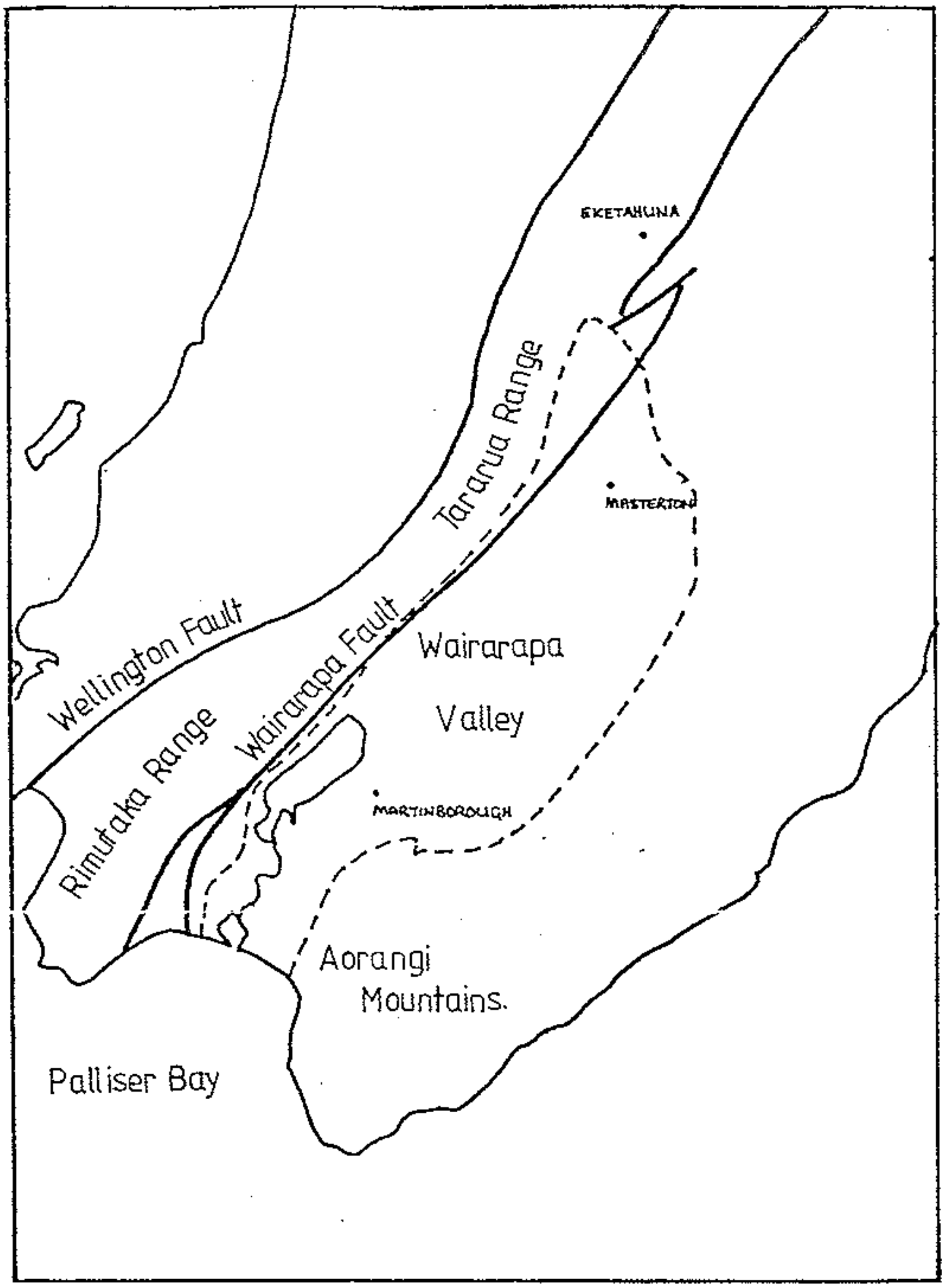


Figure 2 Extent of the Wairarapa Valley

Wairarapa valley (the area within the dashed line) is 77 km long and up to 20 km wide. The Western boundary is marked by the steep eastern face of the Rimutaka and Tararua Ranges, and the eastern boundary by the Aorangi mountains.

Plate 1 Lake Wairarapa and the Onoke bar

Lake Wairarapa (top right) heads a riverine and lacustrine complex which ends at Lake Onoke (middle left) when water enters Palliser Bay via an outlet in the shingle bar. At the top right of the photo can be seen the diversion channel which prevents normal flow from entering Lake Wairarapa.

LAKE WAIRARAPA.

Lake Wairarapa is a large shallow lake with a length of approximately 18km and a width of about 6km, its length-wise axis striking north-east almost parallel to the Rimutaka Range (Wairarapa Catchment Board 1985). At normal levels it has an area of 7 800 ha (similar to Wellington Harbour), a maximum depth of approximately 2.6m and an average depth of only 1.37m (Voice 1982, Wairarapa Catchment Board A).

Reduction of lake level in summer exposes extensive areas of flats, particularly on the eastern side where the Tauherenikau and Ruamahanga Rivers have formed large deltas where they enter the lake. The Tauherenikau delta contains coarse sand and gravel while the Ruamahanga River delivers large quantities of sand and finer material (Voice 1982, Palmer 1982).

The shallowness of the lake means that strong persistent winds create wave action stirring up sand and silt from the bottom, large quantities of suspended sediments giving the lake a brown turbid appearance. In calm conditions these suspended sediments, along with sediment carried into the lake by tributaries, settle out onto the lake bottom or on the mud and sand flats of the eastern shore (Wairarapa Catchment Board 1985, Voice 1982).

The strong winds also cause 'set up' to occur across the lake, prevailing westerly winds pushing water in front of them, tilting the water surface and lifting levels on the eastern side (figure 3). A difference of 1.2m in level has been measured from west to east across the barrage at the southern end of the lake. The nodal point (i.e. zero water level change) is closer to the western shore leading to the set up on the eastern shore being approximately fifty percent greater than the set down on the western side. The winds create steep, breaking waves, up to 1m in height, these winnow silt and clay from the sediments along the eastern shore, leaving the sand fraction behind. Waves of more than 45cm occur less than one percent of the time (Pickrill and Irwin 1978, Wairarapa Catchment Board 1985, Voice 1982).

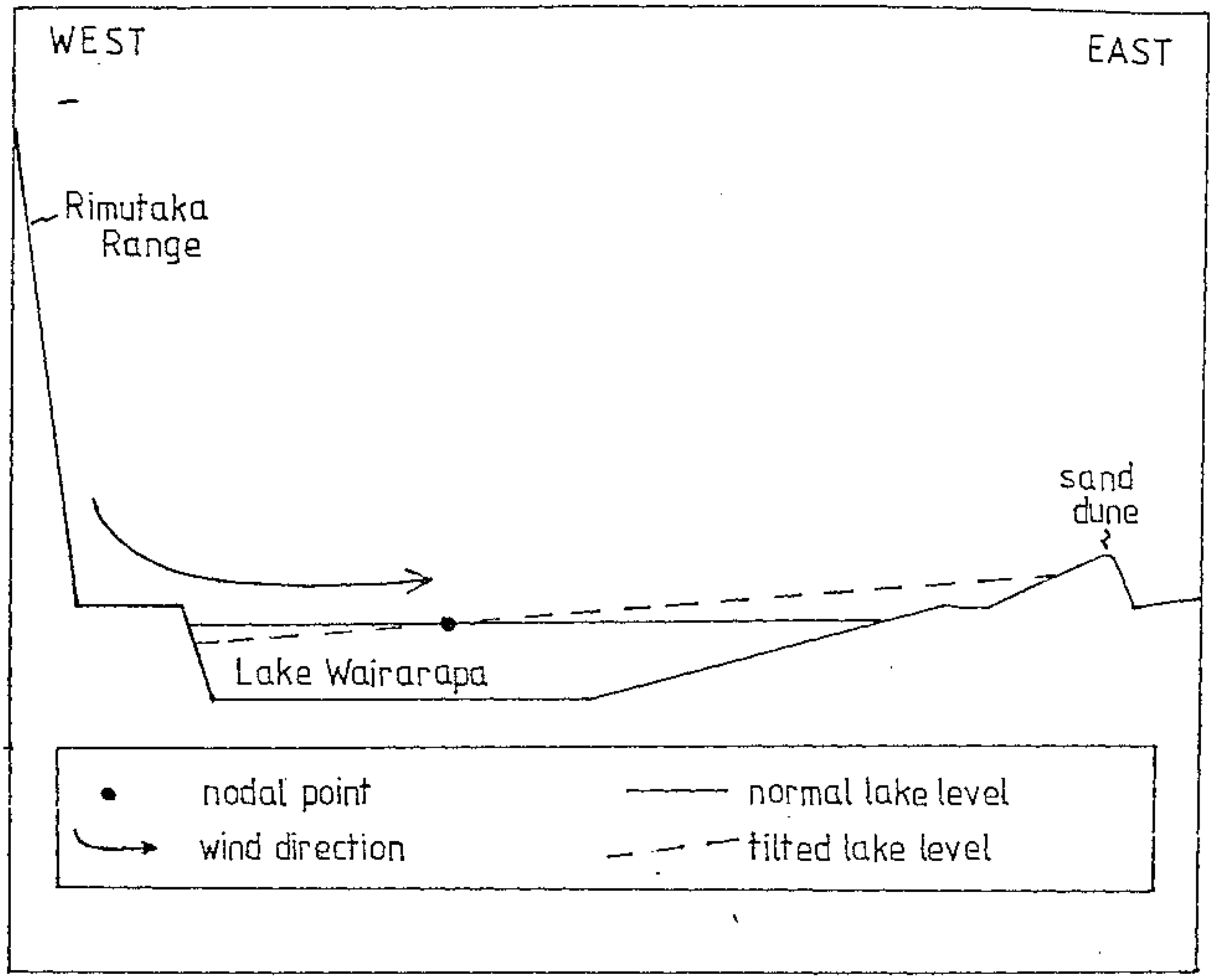


Figure 3 Illustration of set up.

The block diagram above (not to scale) illustrates the phenomenon of set up. This occurs when strong winds push up water in front of them, tilting the lake surface. The nodal point is the point of zero change of water level. As it is closest to the western shore the amount of fall in lake level on the western side is less than the rise in lake level on the eastern side.

HIGHEST HOLOCENE SHORELINE AND MARINE CUT TERRACES.
Around Lake Wairarapa are found beach ridges, sand dunes and cliffs cut into older surfaces (Palmer 1982, Heath 1979). Their distribution, and the discovery of *in situ* shell beds composed of typically estuarine species buried beneath lake and river sediments, show that the area was recently occupied by an estuary (Leach and Anderson 1974). The outermost features represent the furthest incursion of the post-glacial sea level, and therefore mark the highest Holocene shoreline (HHS) (figure 4), (Heath 1979).

Within the study area are a series of dune lines, parallel to the eastern shore of Lake Wairarapa. The oldest outermost dune sits above a cliff cut by the HHS. The succession of dune lines is associated with the receding shoreline of the estuary/lake since the dune formed (Heath 1979, Palmer 1982).

The Holocene incursion is not the first to occur in the Wairarapa Valley. Terraces found on both sides of the valley were formed by previous marine incursions. These marine terraces or marine benches were created by the landward cutting of a marine cliff, and have been preserved from subsequent high sea-levels by regional tectonic uplift (Ghani 1978, Palmer 1982).

1.3.0 Climate of southern wairarapa.

The weather of the Wairarapa region is controlled to a large extent by the presence of the Rimutaka and Tararua Ranges (Figure 2). These ranges exert a strong influence on the distribution of rainfall in the valley, as well as modifying wind directions (Thompson, 1982).

WIND
The Wairarapa region is windy, particularly in spring and summer. Cook Strait and Manawatu Gorge tend to funnel westerly winds, producing south-westerly and north-westerly winds respectively.

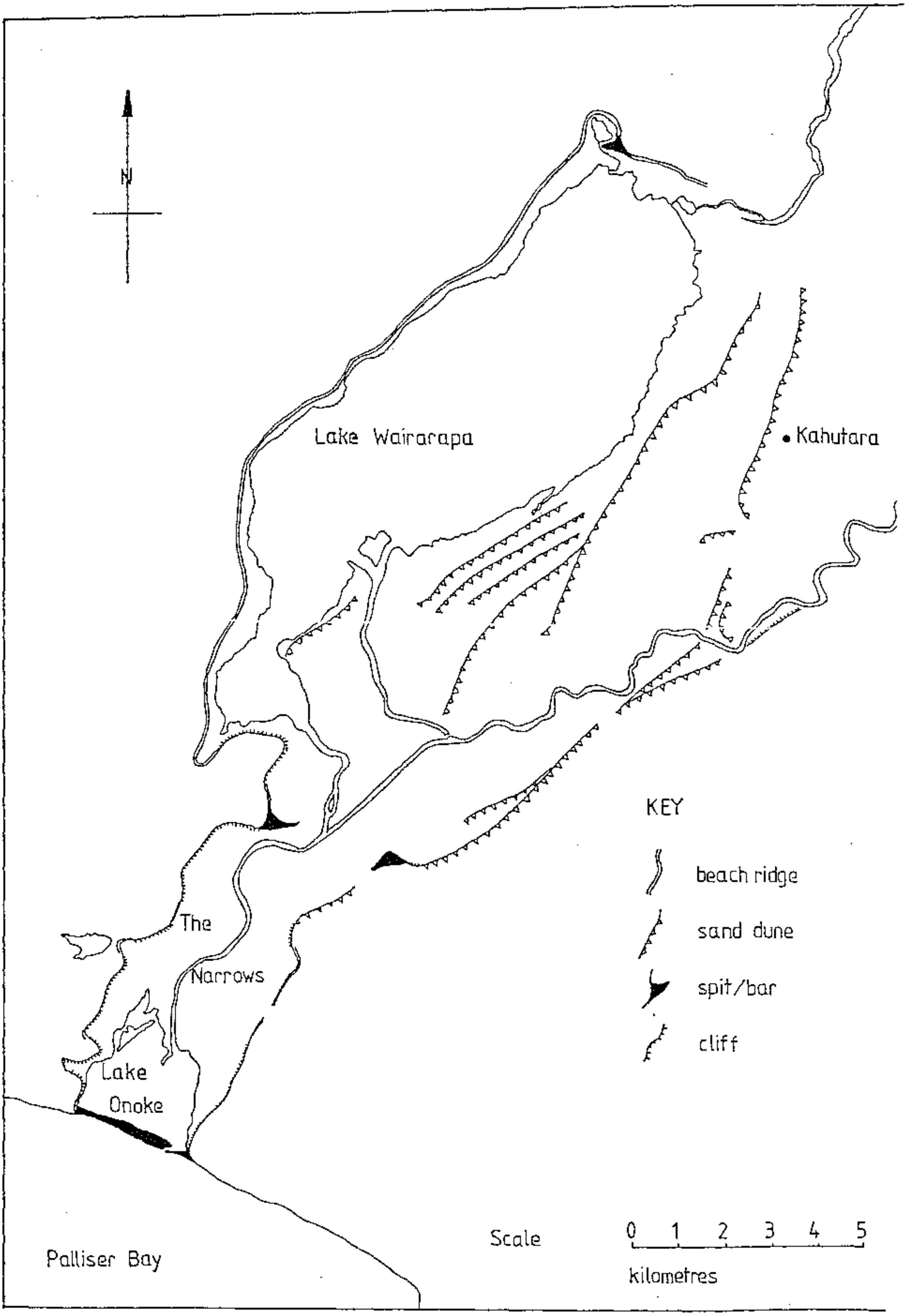


Figure 4 Extent of the highest shoreline (from Heath 1979)

Lake Wairarapa is a windy location with prevailing winds from the north-west (23%), south-west (17%), and north (19%). Wind from the north-east (13%), and south (12%), are the next frequent, with calms (< 3 knots) only occurring 3% of the time (Thompson 1982). Figure 5 shows the direction and speeds of winds recorded at the Barrage, south of Lake Wairarapa. The westerly winds are important to the soils of the study area, as they are responsible for the formation of the sand dunes on which many of the soils have developed.
Mean monthly wind speeds from Lake Wairarapa, Waiorongomai and Papatahi stations on the north, south-west, and southern sides of Lake Wairarapa respectively, range from a low of 8 knots to a high of 16 knots. Mean annual averages from the three stations total 12, 13 and 9 knots. Strong winds (i.e. those over 30 knots) blew for 4.3% of the time at Lake Wairarapa station (Thompson, 1982).

There is not a great deal of variation in wind speed throughout the year, although there is a strong diurnal variation. Wind is generally at a minimum at night as radiational cooling increases the stability of the atmosphere, and at a maximum in the afternoon when lower layers of the atmosphere are least stable due to surface heating.

RAIN

Rainfall has a winter maximum and a summer minimum. Strong frequent westerlies during summer months produce a foehn wind effect, often leading to dry spells and droughts away from the ranges. This is because the ranges shelter the lowlands during prevailing westerly winds, most rain falling in the ranges themselves, with showers on land adjacent to the hills, and dry winds on the plains. Rainfall can be as high as 3000 - 6000mm annually in the ranges, decreasing rapidly from approximately 1500mm to 800mm from west to east across the plains (Thompson 1982, Heine 1975).

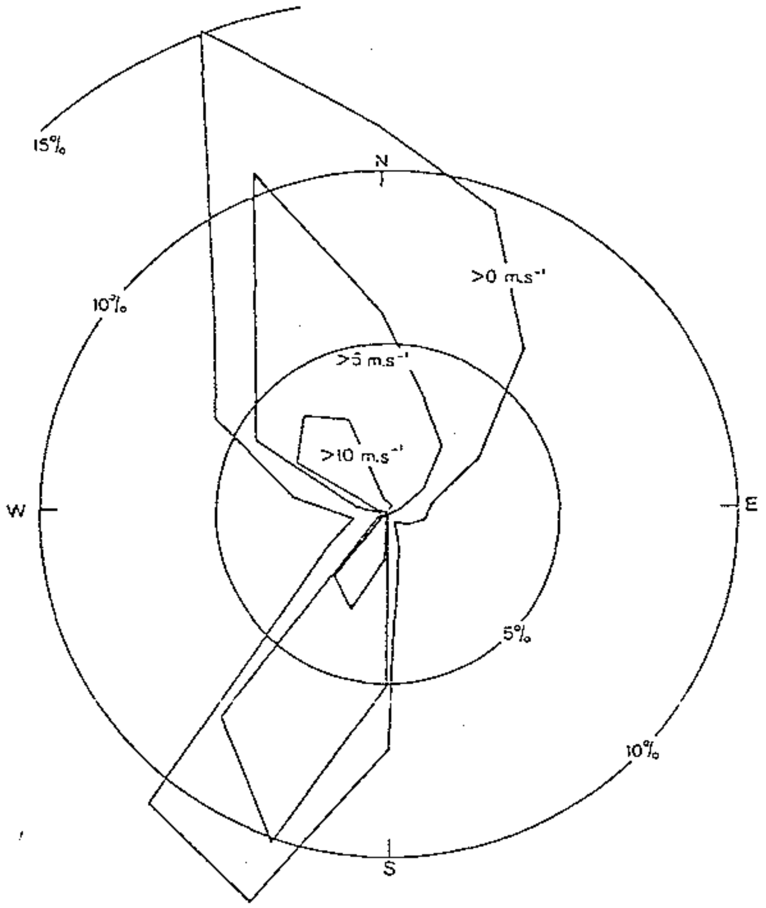


Figure 5 Windrose

Frequency and speeds of winds from different directions at the Barrage meterological logical station, Ruamahanga River, 1973-75 (from Pickrill and Irwin 1978)

As rainfall totals decrease away from the ranges, the distribution of the rain becomes increasingly seasonal leading to frequent summer droughts in the east.

Rainfall in the study area follows the usual Wairarapa trend of a winter maximum and a summer minimum, with 32% of the total falling in the winter months of June - August, and 20% in the summer months of December - February, with 23% and 26% in spring and autumn respectively (Thompson, 1982).

Isohyets from Thompson (1982) show that the area receives an annual average of between 1000 - 1200mm of rain. Rainfall totals around Lake Wairarapa decrease from west to east with annual averages from Featherston and Waiorongomai being higher than those at Martinborough and Pirinoa.

FLOODS

The headwaters of the Ruamahanga River rise in the Tararua range near Mt. Dundas, and many of its tributaries also drain the Tararua range. Consequently heavy or persistent rain in the Tararua range causes river levels to increase and may lead to serious flooding in the lower plains. Heavy rain in the Tararuas can be caused by moist easterlies being forced to ascend the steep sided ranges, or, by north westerlies which although producing a rain shadow effect in the Wairarapa valley, leads to rain in the hills (Thompson, 1982). Heavy rain from the south can also cause flooding in the central and lowland plains (Heine, 1975).

TEMPERATURE

The Wairarapa region experiences sharp and sudden changes in temperature and has a larger daily temperature range than is found in most coastal districts.

At Waiorongomai, the mean annual temperature is 12.3°C. Mean monthly temperatures range from 7.6°C in July to 16.8°C in February, with extreme temperatures recorded being a minimum of -3.1°C, and a maximum of 32.5°C (Thompson, 1982).

The soil temperature is very sensitive to site conditions, but is generally at a maximum in January to February and a minimum in July. At Waoiorongomai the mean annual 9am soil temperature at a depth of 30cm is 13.5°C (Thompson, 1982).

The study area receives approximately 1850 hours of sunshine a year, about 45% of the total possible. There are generally 35 to 55 days per year with no sunshine (Thompson, 1982).

FROST

The study area has on average 29 days of frost a year, compared with 102 days at Masterton, showing the ameliorating effect of the lake. Two thirds of these frosts occur between March and September (Heine, 1975).

FOG AND HAIL

Low lying areas near the lake have a mean annual total of 18 days of fog per year. These are mostly radiation type fogs which occur on calm nights at any time of year (Thompson, 1982).

Hail, thunder and snow are all infrequent phenomenon.

1.4.0 History of the Wairarapa.

1.4.1 Introduction.

There is firm archaeological evidence that the Maori permanently occupied the Wairarapa coast for at least 800 years, and it is likely that the first settlers reached Palliser bay by about 1000 AD (Bagnall 1976 and Leach 1981). Archaeological sites have been found in the Western Lakes area, the eastern valley sand dunes, eastern valley lowlands, river valleys running into the Aorangi Mountains and Palliser Bay, concentrated at the mouths and inner reaches of river valleys draining the Aorangi Mountains (Leach 1981). There were 2 different types of settlement; an earlier permanent settlement along Palliser Bay, and a later occupation of the Ruamahanga Valley.

1.4.2 Early Maori occupation.

The Maoris who settled along Palliser Bay were foraging horticulturalists; cropping kumara, gourd and fern root as well as exploiting birds, fish and shellfish. They occupied the area on a permanent basis, though there seems to have been a seasonal shift from summer dwellings in coastal areas to more sheltered river valleys in the winter. The variety of imported stone used as tools is taken as proof that they traded with other groups of Maori from the Central North Island and the South Island (Leach 1981).

In the period 1250-1450 AD the number of birds caught decreased, probably reflecting the encroachment of gardens into nearby forested areas. As the climate slowly deteriorated through the period Circa 1450-1550AD (figure 6) forest clearance promoted erosion, leading to high sediment loads in local rivers. This caused the sensitive filter feeding shellfish to disappear from the region as evidenced by the content of middens. Bones examined from individuals who lived in this period show evidence of malnutrition (Leach 1981). There was probably also extensive sedimentation around the lake shore during this period.

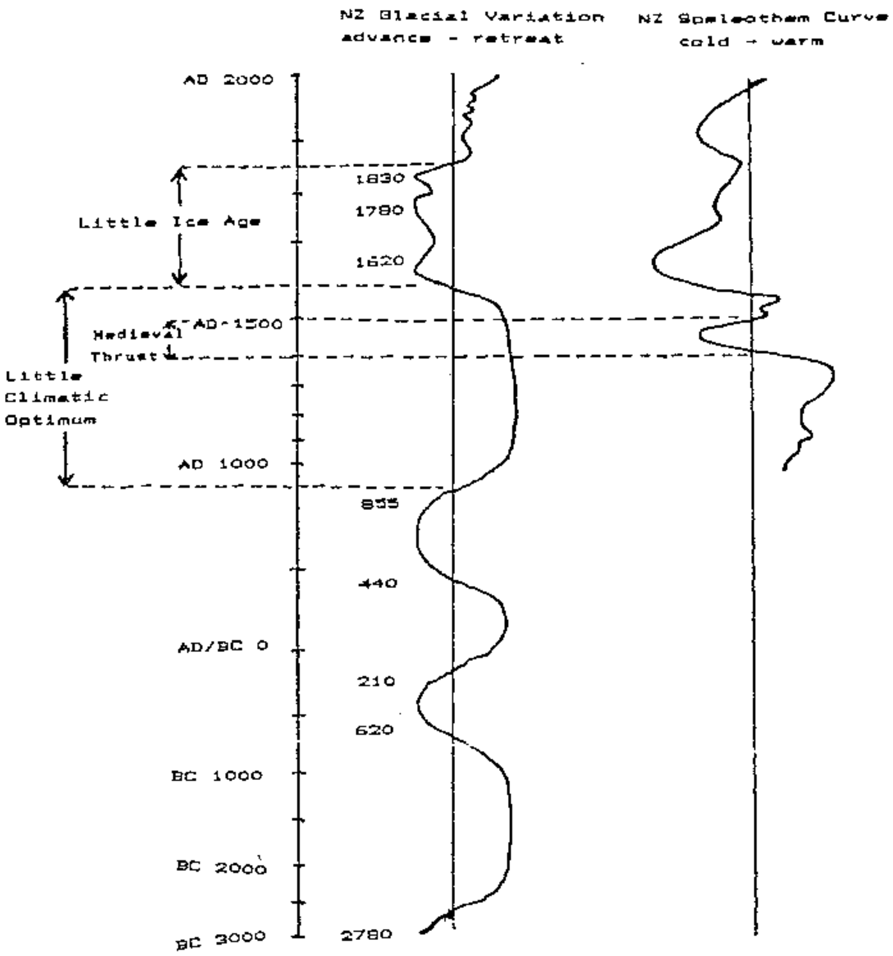


Figure 6 Recent climatic changes in New Zealand (from Leach 1981).

During the little ice age which began about 1600 AD (figure 6) the weather worsened accelerating erosion. Erosion in the ranges led to the formation of shingle beaches, braided shingle rivers and gravel fans. During this period there was a progressive abandonment of the area, the Rangitane people gradually moving to the South Island. It was about this time that the Ngati-Kahungunu migrated to the Wairarapa from Poverty Bay via Heretaunga. The remaining Rangitane exchanged their lands for canoes and weapons, oral traditional holding that they finally left the area about the year 1625 AD (Leach 1981).

1.4.3 Later Maori occupation.

Occupation of the coast was next to impossible because of the widespread erosion and lack of marine food caused by the over exploitation by the Rangitane. The Ngati-Kahungunu settled in the Ruamahanga River valley making only periodic fishing trips to the coast. Kumara production was marginal in the valley therefore fern roots, birds, berries and rats were common foods, eels being especially important. The periodic closure of the shingle bar between Lake Onoke and Palliser Bay (diagrams 1 & 2, and plate 1) caused water to back up the river system flooding the low lying lake margins. This enclosure and flooding of the lakes led to enormous catches of migrating eels, estimated at 10-30 tonnes per year. These eels were dried and traded throughout the North Island (Leach 1981).

This existence carried on until approximately 1770 AD which marked a period of upheaval with various war parties visiting the Wairarapa. By 1835 AD the population had fallen from a high of about 900 to approximately 100 due to migration to the Mahia area (Leach 1981).

When the treaty of Waitangi was signed in 1840 it was believed that land rights reverted to the situation immediately before the mass migration and many of the Ngati-Kahungunu returned to the Wairarapa (Leach 1981).

1.4.4 European settlement.

EARLY EUROPEAN OCCUPATION.

The Wairarapa region was not explored by Europeans until Robert Stokes, a surveyor, along with J.W.Child, two carriers of provisions and two Maori guides made the pioneer crossing of the Rimutaka Range in November 1841 (Bagnall 1954). By 1844 stockholders were arranging to take stock to the Wairarapa despite official displeasure as the land had not yet been bought by the Government (Bagnall 1976).

Duke, Bidwell, Weld and Vavasour leased land off the Maori for £12 per annum. They were regarded as squatters by the government of the day. Stock was driven around the coast where there was good feed. At Mukamuka rocks it was necessary even at low tide to stand in the sea and pass the sheep around, hand to hand. This obstacle was removed when the 1855 earthquake raised the coastal track (Bagnall 1954 & 1976). A year later twelve stations were listed in the area and by 1848 runs occupied a considerable part of the valley (Bagnall 1954 & 1976). Stock had a large impact on native vegetation, cattle being fond of the broadleaf componment of the broadleaf/podocarp forest (see section 1.5.2 for details), (Hill 1963).

Wakefields scheme of colonisation didn't provide for the smallholder and a shortage of land round Wellington forced settlers to look further afield. A dense Maori population on the west coast delayed settlement in that region. A crown title was required before settlers could officially occupy land, and Donald McLean was sent to negotiate with Wairarapa Maoris for land in 1850. The nucleus of the Small Farms Association first met in March 1853 when a formal request was make for land in the Wairarapa (Bagnall 1954).

OFFICIAL SETTLEMENT.

In 1854 Grey and McLean purchased large blocks of land in the Wairarapa, including 200 000 acres in the Western Lakes block and 120 000 acres on the eastern shore of Lake Wairarapa. Part of the agreement was to leave a

100 foot wide thoroughfare either side of the Ruamahanga River to afford the natives free access to their several cultivations on the banks of the river, and the land between normal lake levels and the high water mark was to stay in Maori possession. Also promised was that the channel in the barrier between Lake Onoke and Palliser Bay would not be opened without Maori authority (Bagnall 1976).

With land having been purchased, the Wellington provincial government constructed a one way road for wheeled traffic from Upper Hutt over the Rimutaka Range to the Wairarapa Valley in three years. By 1856 the northeastern highway was completed at a cost of £35 000. It took two horses with a cart two days to make the journey in good weather, necessitating 'inns' at strategic points of the crossing to provide accomodation for both people and stock (Bagnall 1976).

The 1855 earthquake raised the coastal track but no upheaval was recorded on the eastern side of the lake, although a tidal wave swept away the Te Kopi whares (Bagnall 1976).

1.3.5 The struggle for control of lake levels.

Early runholders in the southern Wairarapa were not worried by regular flooding of lake margins, but once the land was surveyed and freeholded the loss of valuable grazing became unacceptable to the settlers. The gap in the shingle barrier between Lake Onoke and the sea was normally closed from December to March causing flooding over a wide area. The settlers wanted to drain as much of the lake as possible and in 1871 threatened to open the lake to the sea by digging a channel (Bagnall 1976).

The Ruamahanga River Board was esablished in 1886 financed by levy of those affected by flooding. The Maoris offered to keep the lake channel open for ten months each year but the offer was rejected by the River Board who declared the lakes to be a public drain in 1888. The Maoris made a formal protest following which the lake was opened, and the Board arranged a clause in the 1889 Public Works Act giving it power to open the lake. In 1891 the Maoris were entitled to two months closure but after that period a fine should be paid for each acre still affected by flooding (Bagnall 1976).

A confrontation occcurred in May 1892 when settlers tried to dig an opening through the bar. As they dug, Maori women filled in the channel behind them. The settlers prosecuted for obstuction and the court ruled in their favour. Finally in 1896 the lakes were sold for £2 000 (Bagnall 1976). Further developments in the battle to control flooding in the area will be dealt with in chapter five.

1.5.0 Past vegetation.

1.5.1 Early European descriptions.

The surveyer Robert Stokes who was in 1941 one of the first Europeans to visit the Wairarapa reported;

> 'the land appeared for the most part to be covered with a coarse grass while on the banks of the river and in different parts of the valley were large groves and belts of trees' (Bagnall 1976).

The Europeans found the Wairarapa to be characterised by variety, the area being a patchwork of grass, swamp, scrub and forest, (figure 7), (Hill 1961). Vegetation changed in a broad pattern from west to east across the valley in the region of Lake Wairarapa. In the west mixed podocarp/ broadleaf forest extended down the Rimutaka Range to the lake margin. On the eastern side of Lake Wairarapa was an unforested swamp. Grasses, tussock, scrub and forest extended over the plains and hillsides to the forested Aorangi Mountains (Bagnall 1976, Hill 1963).

WESTERN RANGES

These were covered in broadleaf/podocarp forest. Species present included pukatea, kanuka, black beech, *Pittosporum, Myrsine*, lemonwood, titoki, nikau, cabbage trees, sedges, *uncinias* and ferns (Tompkins 1987).

SWAMPS AND WETLANDS.

Swamp vegetation was dominated by grasses, raupo, rushes, sedges and flaxes with scattered kahikatea and cabbage trees, *Epilobium* and *Myrophyllum spp.* also being common (Hill 1963, Tompkins 1987).

Along the eastern side of the lake, areas of raupo dominated swamp are interspersed with water milfoil (*Myriophyllum propinquum*), sedges (*Carex* and *Scirpus*) and jointed rush (*Leptocarpus*).

There are areas of flax, toetoe, manuka, cabbage trees and *coprosma propinqua* with a few slender kahikatea, ribbonwood (*Plagianthus*), kowhai, lacebark and ngaio (*Myoporum laetum*) further from the lake, inferring that previously more extensive areas existed (Tompkins 1987).

Native wetland plants include buttercup (*Ranunculus limosella*), and small sedges *Carex cirrhosa, C. bucananii, Eleocharis pusilla* and *Gratiola sexdentata* (Tompkins 1987).

TUSSOCK/GRASSLAND VEGETATION.

Lowland short tussock contained codominant *Poa anceps* and *Festuca littoralis*, along with *Agrostis parviflora* and *Danthonia spp.*. Interspersed with the graminae were umbellifearae such as *Angelica spp.* (aniseed or Maori anise) and *Aciphylla squarrosa* (porcupine grass) (Hill 1963).

FORESTED FLATLAND AREAS.

Where poorly drained land was forested kahikatea-pukatea/tawa forest was the most common combination, with titoki and matai dominating on slightly drier ground (Tompkins 1987).

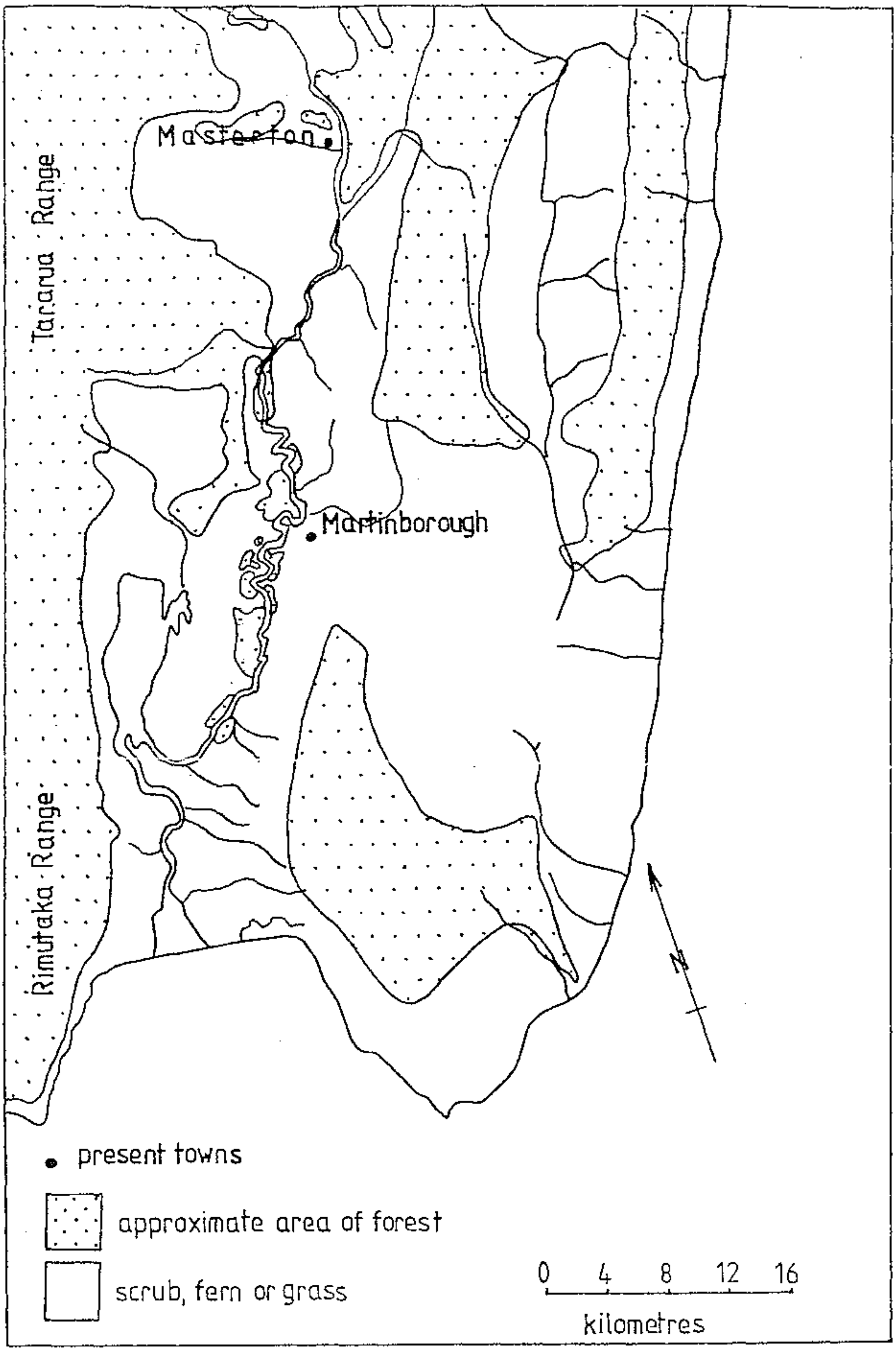


Figure 7 Wairarapa vegetation c. 1853 (from Hill)

The Tuhitarata Scenic Reserve has a canopy dominated by kahikatea, pukatea and titioke; with karaka (*Corynocarpus laevigatis*), mahoe, Corprsma spp., kohuhu, *Fuschia spp.* and ferns found in the understorey (Tompkins 1987).

EASTERN HILLS AND RANGES

Brees and Tiffen travelled to the Wairarapa in 1843 and reported that 'the eastern side of the lake appears to consist of a number of terraces which are mostly free of bush' (Bagnall 1976). The hills were largely fernclad, the ferns interspersed with *Angelica spp.* and grasses (Hill 1963).

The Aorangi Mountains weere covered with podocarp/broadleaf forest with some beech about 880m (Hill 1963).

1.5.2 Effect of the European settlers.

As plently of unforested land was available for grazing there was not much need to burn the forest. Scrub, fern and tussock were regularly burned however to promote fresh growth for stock to graze (Hill 1963).

Cattle and sheep had a significant impact on the natural vegetation. Cattle 'eagerly devoured' broadleaf forest shrbs and juvenile trees, karaka being a particular favourite. Sheep made several species extinct, eating *Angelica* and *Aciphylla*, also the coastal fern (*Anogramma leptophylla*), the native carrot (*Daucus brachiatus*), *Lepidium olearaceum* and *senecio greyii* (Hill 1963).

Common English pasture species were sown by settlers, for instance sweet vernal grass (*Anthoxanthum odoratum*), timothy (*Phleum pratense*), Yorkshire fog (*Holcus lanatus*), cocksfoot (*Dactylis glomerata*) and couch (*Poa spp.*). Australian grass and weed species were also introduced, being brought into the Wairarapa tangled in the wool of imported merinos (Hill 1963).

CHAPTER TWO: GEOLOGY AND PHYSIOGRAPHY.

2.1.0 Literature review.

2.1.1 Introduction.

New Zealand lies at a convergent plate boundary. Below the North Island the dense oceanic crust of the Pacific Plate to the east is subducted north-westwards below the lighter continental crust of the Indian plate to the west (Kamp 1982). As the oblique subduction of the oceanic Pacific Plate occurs, sea floor sediments are scraped off and accreted to the base of the overriding Indian Plate. The sediments form an accretionary prism (or wedge) on the lower continental slope. This accretionary prism is typified by seaward growth and landward understuffing as individual wedges of sediment are thrust upwards on reverse faults (Kamp 1982, Pettinga 1982).

The interaction of the plates has caused the late Cenozoic folding and faulting accompanying the regional uplift of the New Zealand landmass. The most intense deformation occurs in a belt 70 to 100 km wide, extending from Fiordland to Hawke's Bay. Both the Wairarapa and the Southern and Central Hawke's Bay regions lie within this north-east striking mobile belt in a geological zone termed the East Coast Deformed Belt. The East Coast Deformed Belt is characterised by active compressional tectonics with a pronounced north-east to south-west structural grain. Due to the oblique convergence of the plates, movement can be resolved into a compressive vector and a strike-slip (transcurrent) vector. As plate convergence becomes increasingly oblique in the Wairarapa, there is a corresponding increase in the strike-slip component of movement (Ghani 1978, Kamp 1982, Pettinga 1982).

The landforms of the East Coast Deformed Belt are the surface expression of the crustal forces created by the oblique subduction of the Pacific Plate beneath the North Island. Three distinctive landform terrains extend from Central Hawke's Bay through to Southern Wairarapa.

(1) Axial ranges in the west

(2) Central lowlands (plains and low hills)

(3) Eastern hill country (uplands)

Synclines and anticlines in the central lowlands, and tight reverse faulted folds in the eastern hills are caused by compressional forces. Active dextral transcurrent faults (especially those at the foot of the axial range) accommodate most of the strike-slip movement. Both the axial ranges and the coastal hill country continue uninterrupted to Cook Strait, but the central plains are interrupted near Eketahuna (Kamp 1982, Pettinga 1982).

Present day landforms of the Wairarapa region have developed in response to active faulting, tilting and folding accompanying the rapid uplift of the Kaikoura Orogeny (Palmer 1982). The result of continuing tectonic uplift of basement rock has been the formation of a young landscape, mid-late Quaternary in age. The basement rock of the rising ranges is exposed to weathering and erosion in the humid temperate climate, with consequent deposition in the lowlands (Kamp and Vucetich 1982, Palmer 1982).

2.1.2 The western ranges.

The Rimutaka-Tararua Ranges west of the Wairarapa Valley are composed of highly faulted and folded Mesozoic greywacke and argillites, as are the Aorangi Mountains to the east (Kingma 1967).

The Wairarapa Fault is a major active dextral oblique-slip fault which marks much of the western boundary between the Rimutaka-Tararua Ranges and the Wairarapa Valley (Figure 8) (Kamp and Vucetich 1982, Palmer 1982). To the west the ranges rise to over 1 000m (Palmer 1982), while to the east, gravity surveys show that up to 3 200m of Cenozoic material overlies the basement greywacke in the fault angle depression created by movement along the fault (Hicks and Woodward 1978).

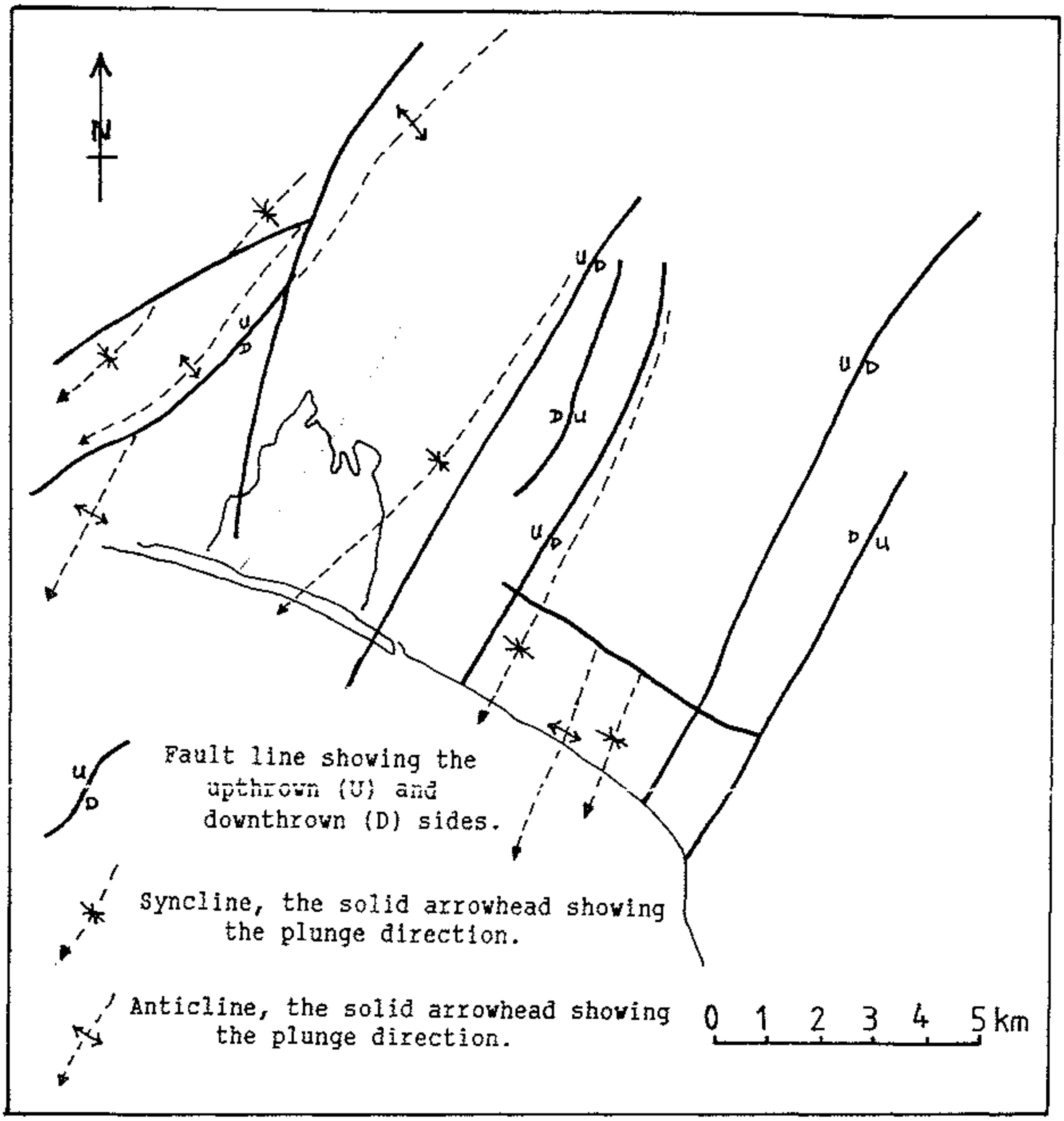


Figure 8 Faulting and folding of the southern Wairarapa Valley.

The East Coast Deformed Belt is characterised by north-east striking, steeply dipping, reverse faults, and active synclines and anticlines. These features are caused by compressional forces, created by the oblique subduction of the Pacific Plate below the Indian Plate.

The ranges are still growing, and the uplift which occurred in the 1855 earthquake is the most recent of a long series of movements which have lifted the ranges to their present height (Stevens 1974a). The 1855 earthquake is estimated to have had a magnitude of 8, and the Wairarapa Fault moved 2.7m vertically and 12m horizontally (figure 9). The movement was in the form of a tilt with the amount of uplift decreasing to the west, totalling 1.5m in the Wellington city area (Stevens 1974b).

Six uplifted marine beach ridges termed A to F by Wellman (1969) are exposed at Turakirae Head at the southernmost tip of the Rimutaka Range. The youngest ridge, A, has formed since the earthquake of 1855, and the oldest, F, is considered to have formed immediately after the post-glacial rise in sea-level (i.e. part of the HHS). There are no shoreline features between the beach ridges and it is assumed that they developed during periods of standstill, with rapid uplift during earthquakes responsible for the areas between them (Wellman 1969). The ages of the beach ridges have been calculated as; A - still forming, B - 114 years old, C - 509 years old, D - 3 100 years old, E - 4 900 years old and F - 6 500 years old (Stevens 1974b). From this series of beach ridges Wellman has calculated the uplift of the coast at the axis of the Rimutaka Anticline to be about 4mm per year (4m per thousand years), decreasing to zero at Wellington Harbour. The average rate of westward tilting is 0.03 degrees per thousand years (Stevens 1969).

2.1.3 The eastern ranges.

The Aorangi Mountains are also formed of Mesozoic greywacke and argillites, and are readily eroded where they are shattered by faulting (Kingma 1967).

To the north and west of the Aorangi Mountains lie the eastern foothills which are composed of Tertiary marine sediments such as soft mudstone and limestone (Kingma 1967). These sediments were deposited from the late

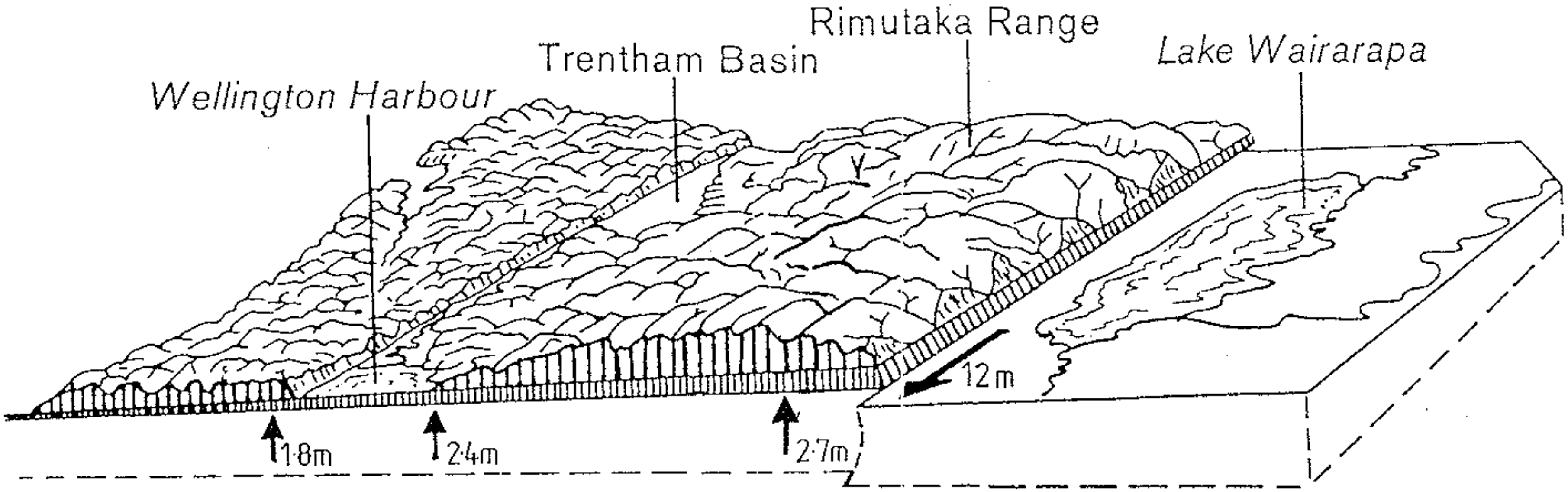


Figure 9 Movement caused by the 1855 earthquake.

When the West Wairarapa Fault moved in 1855 both horizontal and vertical movement occurred as shown above. Upward movement was in the form of a tilt, uplift decreased from the fault towaeds Wellington (from Stevens1974a)

Cretaceous to the early Pleistocene in a marine basin which extended from Marlborough, through Wairarapa and Hawke's Bay to the Gisborne area. The seaway gradually narrowed and closed in the vicinity of Mt. Bruce (Kamp and Vucetich 1982). The sediments have since been faulted, folded and tilted to the west, increasing in age and hardness to the east. These Tertiary sediments are prone to accelerated erosion and in places severe sheet erosion and slumping are widespread (Kingma 1967).

The eastern ranges are still rising, active folding causing tilting and uplift of the area. Wellman (1971) used the emergence height of the highest Holocene beach ridge to estimate the uplift rates of three growing folds on the White Rocks coast near the south-eastern tip of the North Island. His results indicated that average uplift rates were 1.6m per thousand years and 2.7m per thousand years for the Mt Adams and Aorangi Anticlines respectively and 1.1m per thousand years for the Opouawe Syncline.

Ghani (1978) used the heights of four Last Interglacial marine benches to estimate uplift of the south-eastern coast over a longer period of time. The four benches are called the Eparaima marine benches and are designated EA to ED from youngest to oldest, with inferred ages of EA - 80 000 years, EB - 84 000 years, EC - 100 000 years and ED - 125 000 years (Ghani 1978). The Eparaima marine benches were cut during periods of standstill during the Last Interglacial. They consist of a wave cut surface covered by beach deposits and loess, backed by a stranded shoreline at the foot of a marine cliff. The stranded shorelines are lettered SSA - SSD after the associated benches. The four marine benches can be traced along the south-eastern coast from Riversdale to Wellington, flanking the coast, except in the Ruamahanga Valley where they extend up to 42km inland. Uplift rates found by Ghani ranged from 0.75 - 4m per thousand years for growing anticlines and 0.5 - 2.2m per thousand years for growing synclines.

2.1.4 Wairarapa valley.

The seaway between the Wairarapa and Hawkes Bay closed over in the early Pleistocene but a marine environment persisted in the Masterton Basin until the mid Pleistocene. Detritus from erosion of the ranges eventually filled basin floors reversing the general trend of basin subsidence. The fluvial and lacustrine gravels, silts and lignites, and loess of the Te Muna Formation, thought to be between 0.5 - 1 million years old was deposited during this period (Vella 1963, Kamp and Vucetich 1982).

Alluvial deposits forming the valley floor west of the Ruamahanga River have been divided into two groups;

(1) Bruce Group

(2) Plains Group.

The Bruce Group are the oldest preserved aggradation deposits in the northern Wairarapa Valley, resting unconformably on mid Pleistocene marine sediments. The residuals of the former surface are found up to 180m above the Ruamahanga River and have been rounded by solifluction and the deposition of loess. The Plains Group is a group of aggradation surfaces including the Waiohine surface and three terraces formed by the Ruamahanga River in the northern valley. The Waiohine surface is a large composite alluvial fan that lacks a loess cover and is thought to be slightly older than Holocene (Vella 1963).

The Eparaima marine benches are also preserved within the valley. All four are preserved in the coastal part (i.e. the Narrows), but further inland only the oldest and youngest benches are preserved (Ghani 1978)(figure 10). Preservation of the marine benches in the valley, where uplift rates are low, indicates that the sea level in the Last Interglacial was within 10m of the present day sea level (Palmer 1985).

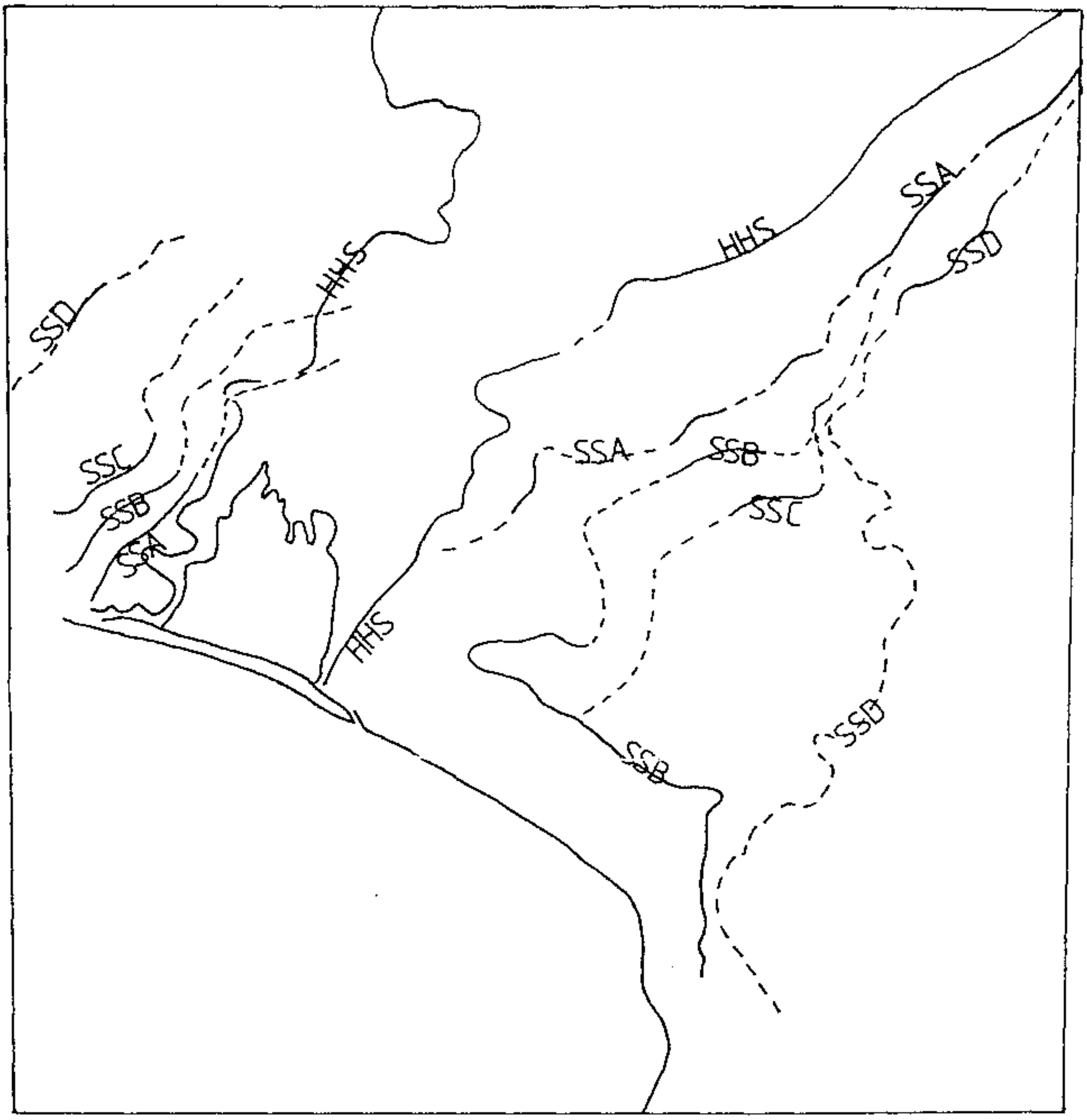


Figure 10 Eparaima marine benches.

The Eparaima marine benches were cut during the Last Interglacial. The stranded shorelines at the back of the benches are termed SSA-SSD from youngest to oldest. Although all four are preserved around the mouth of the Narrows, further inland only the youngest and oldest benches are preserved (from Ghani 1978).

2.1.5 Formation of Lake Wairarapa.

During the last stadial water was held as ice by large continental ice sheets, and therefore sea levels were much lower than at present with part of the present day continental shelf being exposed. Global warming caused these ice sheets to melt leading to a rise in sea level of 135m in the New Zealand area, reaching present day levels approximately 6 500 years ago. Gibb's New Zealand eustatic sea level curve indicates that since 6 500 years before present (BP), sea level has not varied more than 0.5m above or 1m below present sea level (Heath 1979, Palmer 1982).

The postglacial rise in sea-level allowed the sea to flood the Wairarapa Valley forming an estuary Kites (1952) 'Wairarapa sea' connected to Palliser Bay via the 'Narrows' (Heath 1979). The area formally covered by the sea is delineated by shoreline features such as beach ridges, sand dunes and cliffs cut into older surfaces (Heath 1979, Palmer 1982). Collectively these mark the highest Holocene shoreline (HHS) of figure 4. Since the formation of the HHS a combination of progradation of the eastern shore and tectonics have caused the waters of the estuary to recede.

Cotton (1958) regarded Lake Wairarapa as one of New Zealand's few tectonic lakes, tectonic lake basins being formed wholly by movements of the earths crust (Lowe and Green 1987). In this instance the fault-angle depression between the fault scarp of the Rimutaka Range and a warped valley floor surface forms the water holding basin. In contrast Kite (1952) saw progradation of the eastern shore blocking the 'Narrows' as the mechanism by which Lake Wairarapa formed.

Lowe and Green (1987) classify Lake Wairarapa as a lateral lake; these characteristically form when levees back-up tributary drainage water. This classification is based on descriptions by Leach and Anderson (1974) and Stevens (1974b). Leach and Anderson discount tectonic uplift as being important in decreasing the extent of the former estuary, and cite progradation following or accompanied by regional warping as causing the retreat of the estuarine shoreline. Sedimentation and bar development eventually closed the 'Narrows', transforming the area from an estuary into a lake. Stevens (1974b) states that sediment from the Tauherenikau and Ruamahanga Rivers built a natural dam across the seaward end of the basin, thus forming Lake Onoke and converting Lake Wairarapa into a body of fresh water.

Stevens (1973) describes the formation of Lakes Kohangatera and Kohangapiripiri, both of which occupy the lower ends of valleys which were originally long narrow inlets of the sea. The inlets were initially cut off from the sea by the formation of shingle spits, and eventually continuous gravel bars that were widened by tectonic uplift. The inlets were thus transformed into fresh water lakes, draining to the sea by seepage through the shingle bar, sometimes flowing directly into the sea during floods.

Leach and Anderson (1974) provide evidence dating the change from an estuarine environment to the present complex of lakes and rivers. Two sites where *in situ* shell beds were found buried by silts were described in detail (figure 11). The shell beds contained a faunal assemblage typical of estuarine areas. Leach and Anderson considered the fact that many of the bivalves were found as 'closed pairs' suggested that they had died suddenly, the theory backed up by the fact that small gastropods (snails) had not filled with sediment. Radiocarbon dates obtained from the shells range from approximately 3 500 - 4 500 years BP, the former considered to be the time at which the prevailing estuarine conditions of the area changed to a predominantly lacustrine environment.

Kranz (1974) found that suspension feeding bivalves were unable to escape more than 5cm of burial although other organisms could escape from up to 50cm of their native sediment. In all cases burial under sediment of smaller grain size than the native sediment decreased the escape ability of the

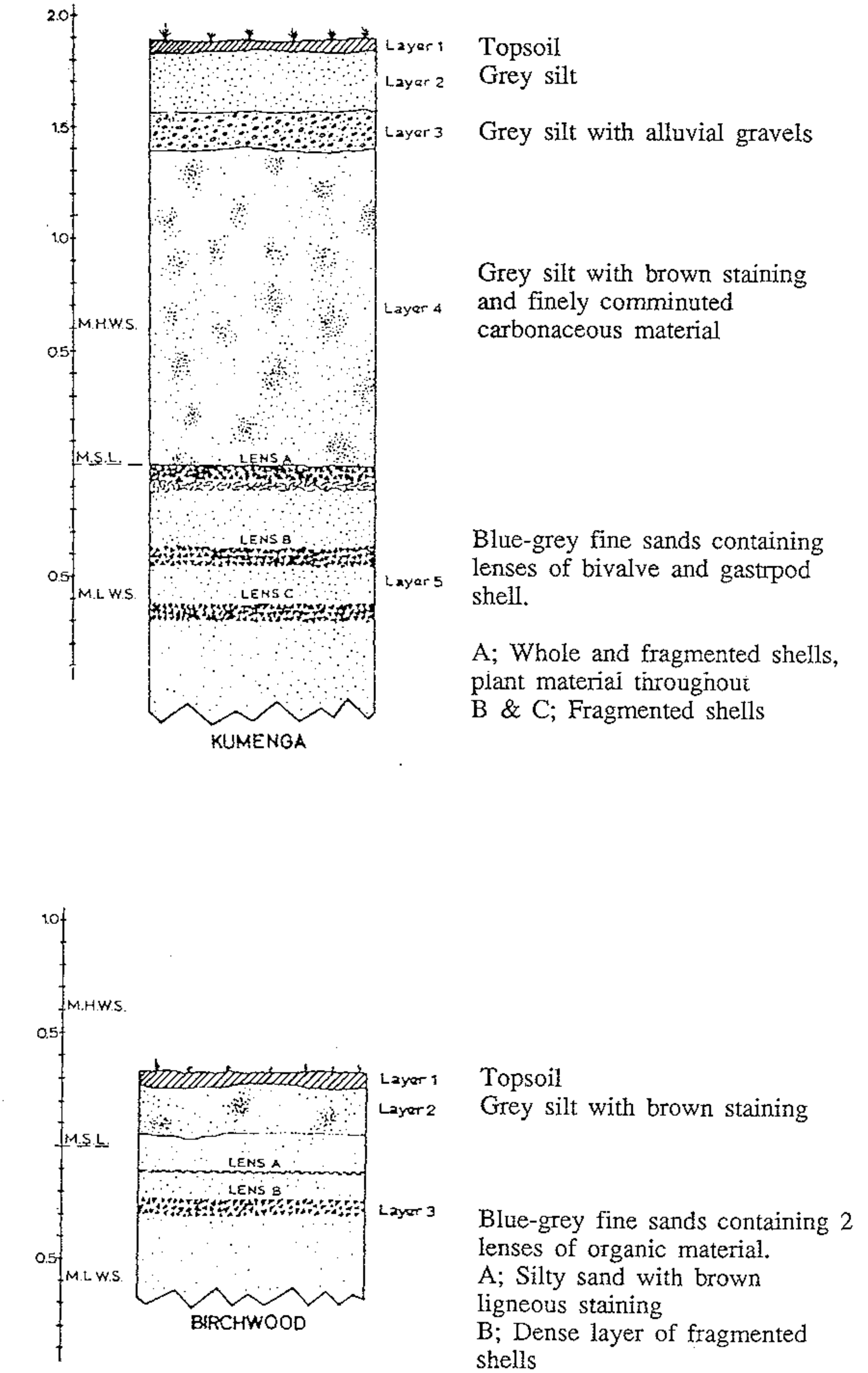


Figure 11 Summary of descriptions of the sites at Kumenga and Birchwood (from Leach and Anderson 1974).

organisms. Nichols et al (1978) reported that while most animals commonly found in soft bottom communities could escape a burial of 5 to 10cm, none even attempted to escape when covered to a depth of 30cm. They suggested that when 'overburden stress' reaches a critical value animals cannot escape. Experimentation showed this overburden stress to correspond to a burial depth of 28cm. If buried at depths greater than this, the organisms did not even initiate an escape attempt.

2.1.6 Holocene sedimentation.

CATCHMENT OF THE RUAMAHANGA RIVER.

Prior to the diversion of the Ruamahanga River the two main tributaries entering Lake Wairarapa were the Ruamahanga and Tauherenikau Rivers. Both have deposited large deltas where they enter the lake (Palmer 1982), however the Ruamahanga River was the main source of sediment being deposited in the lake (Voice 1982).

The Ruamahanga River runs 145 kilometres from the Tararua Range to Palliser Bay, serving as the major drainage channel for a large catchment of almost 3 500 km^2 (Wairarapa Catchment Board, Wairarapa Catchment Board and Regional Water Board 1985). Tributaries of the Ruamahanga River drain the Tararua Range, the Eastern foothills and the Aorangi Range (figure 12). Lakes Onoke and Wairarapa are situated at the lower end of the system and most of the flooding in the catchment occurs in their vicinity (Wairarapa Catchment Board).

NATURAL PROCESSES.

The three kilometre long Onoke gravel bar blocks the entrance of the Narrows, its crest up to seven metres above mean sea-level (Palmer 1982). Lake Onoke is held at close to mean high sea level by the maintenance of an open cut in the bar (plate 1). Prior to catchment board management the gap in the bar gradually closed over in the summer. Water was impounded behind the bar throughout the winter until enough pressure had built up for

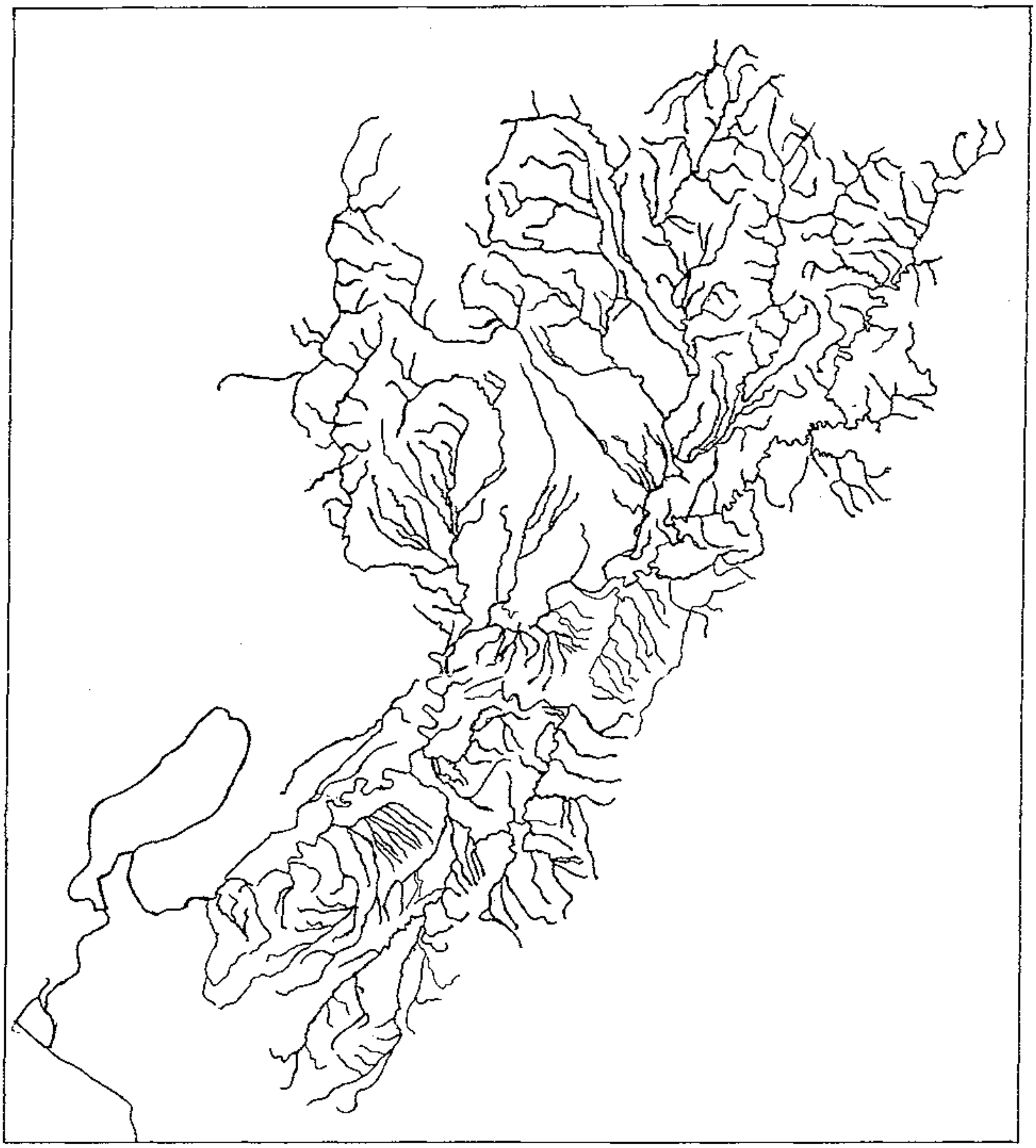


Figure 12 Tributaries of the Ruamahanga River.

The catchment area of the Ruamahanga River covers almost 3 500 km^2. The tributaries drain parts of the Tararua Range, Aorangi Range and the eastern hill country it to break through. During this period water level would rise to four metres above mean high sea level, flooding the area almost to the HHS and backing the Ruamahanga River as far as Martinborough. As much as 20 000 hectares was flooded up to eight times a year (Palmer 1982, Wairarapa Catchment Board and Regional Water Board 1985). This extensive winter flooding contrasted with low summer lake levels which exposed extensive areas of flats especially on the shallow eastern side (Voice 1982). The drying out of the flats commonly led to the occurrence of sandstorms (Wairarapa Catchment Board and Regional Water Board 1985).

SEDIMENTATION OF THE RUAMAHANGA DELTA.

No sedimentation rates are available for Lake Wairarapa, but it is thought that large areas along the eastern shore are composed of a 0.8m thick sandy layer covering old estuarine sands. Evidence indicates that coarse river sand deposited at the Ruamahanga River delta becomes finer towards the centre of the lake and towards the north (Voice 1982).

A study of the Ruamahanga River delta by Pickrill and Irwin (1978) shows that a series of sand bars has developed along its outer edge. The bar system was found to be constantly changing its form via shore normal shifts in the positions of ridges and troughs, with only a negligible change in the volume of material. Three sedimentary environments were identified on the delta from a scattergram of mean grain size against sorting:

(1) Well-sorted medium-fine sands of the foreset and topset delta slopes (except in the troughs of the submarine bars);
(2) Poorly sorted muds in the central basin of the lake, beyond the toe of the sandy foreset slope;
(3) Very poorly sorted bimodal sediments in the bar troughs, made up of two sub-populations, the well-sorted sands of the topset beds and the poorly sorted muds of the central basin.

TUHITARATA DUNE SYSTEM.

The presence of dune lines along the eastern shore of Lake Wairarapa was noted by Leach and Anderson (1974) who considered that they represented stages in the recession of the former estuary. It was suggested that this retreat need not be due to a fall in mean sea level or tectonic uplift, but a decrease in tidal range effected by the narrowing of the seaward end of the estuary.

Seven dune lines were distinguished by Heath (1979) who showed that they are composed of well sorted quartzo-feldspathic sands with a mean grainsize of between two and three phi units (Appendix 1). He also noted the relationship between the orientation of the beach and the dune lines, and the correlation of elongated blowout directions with the prevailing northwesterly wind. Heath considered that the sand was derived from the coastline, transported through the narrows by the impinging southerly swell. An age of approximately 2 000 years BP was proposed by Heath for the formation of the Onoke gravel bar. Accordingly the youngest dunes would have a minimum age of about 2 000 years.

Palmer (1982) notes that the oldest dune line is often preserved above cliffs which are part of the HHS, and that the second main dune line appears to rest on an old beach bar. In contrast to Heath he suggests that the younger dunes could by derived from sand deposited on the lake shore by the Ruamahanga River.

2.2.0 Description of the late Quaternary deposits.

Along with the Tauherenikau River, the Ruamahanga River is responsible for the infilling of the estuary formed in the lower part of the valley by the Holocene marine transgression. The Ruamahanga River has the larger catchment area, and is the river which has formed the plains of the Lower Wairarapa Valley (Wairarapa Catchment Board A). The sediment it has deposited in and around Lake Wairarapa is generally finer than coarse sand, therefore most of the Holocene surface deposits are formed of varying proportions of clays, silts and sands.

The main aim of this study was to map the late Quaternary deposits within the study area (figure 1). The surface geology is described within this section, and the distribution of defined sedimentary units shown on the accompanying map.

Surface geology was examined to a depth of approximately one metre at soil profile description sites (see accompanying map), and to depths of up to four metres where deposits were exposed in roadside cuttings, drains and natural waterways. Borehole log data was examined but not included in this discussion as most of the sites were outside the study area, and there appeared to be little correlation between individual sites.

2.2.1 Deposits of the dunes and sandflats.

UNIT 1: SAND > 90cm deep.

Several dune lines formed from well sorted quartzo-feldspathic sand parallel the lake shore. The dunes range in height from approximately 1 - 30m (see physiographic map), and sections through them show large scale cross bedding on the leeside (plate 2). The raw sand ranges in colour from dull yellowish brown (10YR 4/3) to olive brown (2.5Y 5/3 - 5/4) where it is well drained. Imperfectly drained sands have ochreous mottles, and in poorly drained situations low chroma mottles are also visible.

Between the two dune lines closest to the lake, and forming the lake margin are two sand flats. These are both low lying and very poorly drained, thus the sands they are formed from have abundant to profuse low chroma mottles along with ochreous mottling to the surface. At depths greater than 60cm the sands may be strongly gleyed with solid grey or grey-blue colours.

Plate 2 Dune bedding

The above section is through part of dune set two a few hundred metres north of Judds Road. Cross bedded sand on the leeside of the dune can be seen above the spade and auger, the beds dipping towards the bottom right corner.

The sandflat forming the lake margin is a fluvial/ lacustrine deposit which is part of the Ruamahanga River delta (Pickrill and Irwin 1978).

The sandflat between the two dune lines closest to the lake is of mixed origin. It would have previously been part of the lake margin, but has been cut off from the lake shore by the most recent sand dunes. It has also undergone deflation; sand having been removed from its surface by the wind to form the dune line immediately to the east. Therefore, although originally a fluvial/lacustrine deposit, the sand has been reworked by the wind giving it an aeolian nature.

UNIT 2: SAND 45-90cm; OVER SILT.
In places the dune sand has formed a thin veneer less than 90cm deep over alluvial silts. Where the alluvial silts were very poorly drained, swamp vegetation (rushes and reeds) and sometimes peat were also buried by the sand and can be found at the sand/silt interface.

2.2.2 Deposits of the alluvial plains.

At the mouth of the old Ruamahanga River channel lies the delta formed prior to the diversion of the river in 1968 (Pickrill and Irwin). The sand bank forming the lake margin, covered by high lake levels but exposed when the lake is low, is part of the delta.

UNITS 3 & 4: SILTS < 90cm; OVER LAYERED SANDS AND CLAYS.
Lying close to the lower parts of the river channel behind the widest part of the sandbank are sediments which have also been deposited as part of the delta (see accompanying map of Late Quaternary Deposits). These are composed of varying depths of silt overlying repetitively layered fining upwards sands, sandy clays and clays. Generally the sand layer is the thickest and the clay layer the thinnest, though the units themselves vary in total thickness. These deposits have been divided into two groups; those with less than 45cm of silt covering the layered sediments (unit 3), and

LEGEND FOR THE MAP OF LATE QUATERNARY DEPOSITS
(to accompany the map in the back pocket)

Deposits of the dunes and sandflats

Unit 1; sand > 90 cm

Unit 2; 45 - 90 cm of sand, over silt

Deposits of the alluvial plains

Unit 3; silt < 45 cm of silt, over layered sands and clays

Unit 4; 45 - 90 cm of silt, over layered sands and clays

Unit 5; silt < 45 cm, over sand

Unit 6; silt < 45, over gravels and sands

Unit 7; 45 - 90 cm, of silt over sands and grit or gravel

Unit 8; silt > 90 cm, over sand

those with between 45cm and 90cm of overlying silt (unit 4), (see the accompanying map). The silt cover becomes thicker away from the lake.

These sediments grade into others:

(a) Deltaic sediments with less than 45cm silt cover grade into the sand plain deposits between the two dune lines closet to the lake. This occurs as the silt cover becomes thinner, the number of repeated units becoming less and the amount of clay decreases. Transitional sediments are mostly sand with one or two very thin clay bands within them.

(b) The deltaic sediments with a silt cover of 45 - 90cm grade into the group of alluvial sediments composed of more than 90cm silt.

UNIT 5: SILT < 45cm; OVER SAND.

In some locations there is less than 45cm of silt over sandy material and the overlying silt is commonly less than ten centimetres thick (see accompanying map of Late Quaternary Deposits). This type of deposit is found in hollows and shallow basins close by or on the sand plain. These represent either artificially drained or ephemeral ponds. The ponds would have been small and very shallow, probably less than 50cm deep in many cases, and all less than one metre. Commonly the sands below about 60cm are very gleyed with dark greenish grey - blue colours free of any ochreous mottling. Above these are gleyed sands, sandy clay loams with abundant to profuse low chroma mottles as well as ochreous mottles. The overlying silts are also dominated by pale colours with chromas less than or equal to 2, i.e. greyish yellow (2.5Y 6/2) .

UNITS 8 & 9: SILT >90cm; OVER SAND.

Alluvial deposits with silts deeper than 90cm cover a wide area adjacent to the Ruamahanga River and a smaller one by Mangatete Stream (see accompanying map of Late Quaternary Deposits).

UNIT 9.

The area around the Ruamahanga River is very low lying, mostly between 2 - 4m in elevation. The deposits are fine, textures ranging from silty clay to fine sandy clay loam. Typically the silty clay and silty clay loams are found near the centre of the alluvial plain, the fine sandy clay loams closer to the river. Because they are so low lying and (before the diversion) frequently flooded, the sediments are poorly drained. This is reflected in their colour, with low chroma and ochreous mottles reaching the surface. Channels formed by roots and worms are lined with an ochreous stain/coating.

The alluvial plain contains many shallow basins which are occupied by lagoons unless they have been artificially drained. Where the water is ephemeral or has been drained, the sediments exposed are generally silts and clays to depths greater than 90cm. In the sediments of the larger of the drained ponds (shown by the dashed lines on the accompanying map), the shells of freshwater mussels or *Hyridella menziesi* can be found. They are generally encountered between the depths of 30 -50cm. These elongated oval bivalve shellfish grow up to ten centimetres in length, and spend all of their adult life buried beneath the mud. They are brown on the outside, as all fresh-water shellfish possess a thick brown outer layer to protect the limy inner layers of the shell from the corrosive action of the fresh water (Powell 1967).

UNIT 8.

Silty material is also found to a depth of more than 90cm in the area around Whareroto Road (see accompanying map of Late Quaternary Deposits). This alluvial plain has a slightly higher elevation than the one previously described, with heights commonly between four and six metres above mean sea-level. The plain slopes from the lake towards the river except in the vicinity of the backwater between Judds Road and Whareroto Road (see accompanying map). Where this backwater cuts through the second dune line, the elevation drops to two metres.

The sediments generally have a texture of fine sandy clay loam capped by a 20 -30cm deep layer of silty clay loam and are poorly drained. Low chroma and ochreous mottles are found throughout the fine sandy clay loam textured material, but not often in the overlying silty clay loam. Iron-manganese concretions may be present to a depth of approximately 70cm.

These deposits grade into the coarser ones found in the Judds Road area, the silty layer becoming shallower, and the underlying material coarser.

UNIT 7: SILT 45-90cm; OVER SAND AND GRAVEL.
Alluvial deposits with 45-90cm of silty material over sands and grits are found on the higher alluvial plain between Judds Road and the Oporua Floodway (see accompanying map of the Late Quaternary Deposits). Elevation in this area ranges from approximately four to eight metres. The plain is highest at the base of the dunes and slopes away from the lake towards the river.

The silty sediments range in texture from silty clay loam to fine sandy clay loam and lie over coarse sand which may contain small stones (less than 1cm diameter) by 90cm. Thin layers of silts and clays may be found within these coarse sands. The overlying silty material often contains iron-manganese concretions, but rarely contains discontinuous thin lenses (less than 5cm) of small pebbles (less than 1cm diameter). These deposits are poorly drained, low chroma and ochreous mottles reaching to within 45cm of the surface. At depths between one and two metres the coarse sand gives way to layers of silt and organic material overlying blue-grey sandy muds.

This unit grades into one with more than 90cm of predominantly silty alluvium over sand. It also grades into a unit with less than 45cm of silty alluvium over coarse sands and gravels.

UNIT 6: SILT < 45cm; OVER SAND AND GRAVELS.

Alluvial/fluvial deposits with less than 45cm of silty material overlying coarse sand and gravels are found in the vicinity of the junction of Kahutara and Judds Roads (see accompanying map - Late Quaternary Deposits). The depth to stones, the degree of stoniness and thickness of the stony layers varies greatly over very short distances.

To be included within this unit there must be a layer at least 20cm thick which is stony to very stony[1], and reaches to within 45cm of the surface. The stones range in size from the more usual one to two centimetres to a maximum of seven centimetres, i.e. they are gravels (see appendix 1). Alluvium above and below the stony layer may contain no or only a few stones. The alluvium above, below and between stones usually ranges in texture from silty clay loam to sandy loam, and tends to coarsen downwards. In very stony layers which are clast supported, interstitial material is likely to be medium to coarse sand. Thin lenses of silt and clay may be found in alluvium below the stony layer. Occasionally two stony layers may be separated by sands etc.

One other area which has silty material over coarse sands and gravels covers an insignificant area between the drained bed of Te Hopai Lagoon and the East-West Access Road (see accompanying map of Late Quaternary Deposits). The sediments in question are dune shaped, but the wind is not capable of moving the stones, and silty dunes (lunettes) are not common. Some layering is evident amongst the coarser material but no cross bedding as in sand dunes. A local farmer said that these deposits were tailings removed from the Ruamahanga River channel. Large amounts of material were excavated to widen the existing river channel and create a new one during the diversion of the river. Many hollows on the adjacent Kumenga Peninsula were filled using similar material.

[1] The stoniness of soils is classified as follows: less than 7% stones - with stones; 7-30% stones - stony; more than 30% stones - very stony.

2.3.0 The change from an estuarine to lacustrine environment.

From the evidence presented in the literature review it seems certain that the lower Wairarapa Valley previously held an estuary, its maximum extent marked by the highest Holocene shoreline dated at 6 500 years B.P. (Wellman 1969, Heath 1979, Palmer 1982). Extensive sedimentation has transformed the area into the present day lake and river system. As the lake shore has gradually prograded, intermittent dune building episodes have formed the distinctive dune-lines of the eastern shore.

2.3.1 Theory and discussion of estuarine sedimentation.

Estuaries are defined as the lower courses of rivers which have been invaded by the sea, present day estuaries having been formed when the Holocene marine transgression submerged coastal lowlands (Bird 1976, Davies 1980). Estuaries are ephemeral features as they are typically areas of active sedimentation, being progressively infilled, depth and surface area decreasing until the river eventually flows seawards through a depositional plain (Bird 1976, Dyer 1986).

The estuary formed in the lower Wairarapa Valley had a restricted narrow entrance (The Narrows), broadening out into the main body of the estuary (figure 4). The coastline between Wellington Harbour and Cape Palliser is a high energy coast, exposed to almost constant southerly swell, and has a tidal range of between 0.9 and 1.2 metres (Wellman 1969, Stevens 1973, Leach & Anderson 1974). Thus the Narrows would have been the focus of strong tidal currents (Palmer 1982).

The estuary itself would probably have been a salt wedge estuary, as the essential components of a large river flow and a small tidal range are both met in this situation. Waves passing through the Narrows into the estuary proper would diverge, the shallow water causing dissipation of energy. Both mechanisms decrease tidal range (Davies 1980, Dyer 1986).

In salt wedge estuaries the less dense fresh water discharged from rivers tends to flow out over the surface of the denser sea water. Thus the sea water forms a wedge at the bottom, thickest near the mouth of the estuary, and thinning towards the head. A narrow zone of upward mixing with a sharp salinity gradient, known as the halocline, exists between the freshwater above and the saline water below. The resulting circulation within the estuary is that of salt water moving inwards at the base of the water column, gradually becoming mixed with the overlying, outward flowing freshwater (figure 13),(Davies 1980, Dyer 1986).

The circulation in salt wedge estuaries has a strong influence on sedimentation patterns. Suspended sediment tends to flow out seawards on the surface layer. Any mid-estuary sedimentation tends to take place at the tip of the salt wedge (Dyer 1986). A landward decrease in tidal amplitude (such as in the Wairarapa estuary) means that flood tide currents are strongest at high water, and ebb tide currents strongest at low water. This results in a net landward movement of coarser sediments as bedload. They are transported landward by strong floodtides, and subaerially exposed at low water when ebb tides are strongest (Davies 1980).

Estuaries often have material from adjacent beaches and/or offshore sources transported into their mouths, filling them form seaward (Davies 1980, Derbyshire *et al* 1981). Where the entrance to the estuary is narrow (i.e. the Narrows) and constricted by bedrock, marine sediment is deposited in the form of a tidal delta. Where the tidal range is small and wave action strong, the tidal delta forms a broad sandflat, exposed at low tide, with a single winding channel. Slopes are gentle seaward, but steep inward where sand advances into the estuary from the sea (Bird 1976).

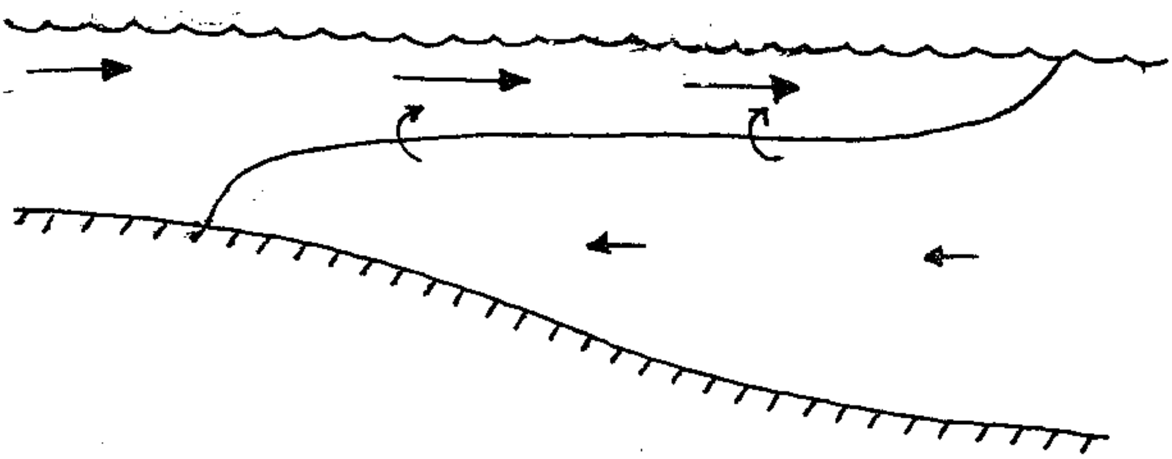


Figure 13 Circulation in a salt wedge estuary.

Fresh river water flows outward over the more dense salt wedge. Upward mixing occurs in a narrow zone called a halocline between two water masses (from Dyer 1986).

Estuaries are also filled from landwards as rivers which discharge into them form prograding deltas (Bird 1976, Dyer 1986). If an estuary is enclosed by spits or barriers the natural reclamation of the area tends to be accelerated. The formation of barriers is encouraged by a low tidal range, an abundance of sediments, a shallow shelf and moderate wave energy The two main modes of barrier origin are the longshore development of spits and the development of emergent beaches offshore (Figure 14). During the Holocene marine transgression many barriers were formed as the rising sea-level swept across areas of abundant sediment supply, reworking the deposits and moving them shorewards (Bird 1976, Bloom 1978, Davies 1980).

Barriers may or may not completely enclose the mouth of an estuary, depending on the relative strengths of currents which flow through entrances, and longshore drift which tends to seal them. Tidal currents and those produced by the outflow of rivers tend to maintain the entrances (Bird 1976). Some estuaries become completely enclosed in summer when rivers are low. When the rivers flood after heavy rain, the water level rises until the barrier is breached thus reopening the entrance. This was the case with the Wairarapa estuary/Lake Wairarapa until the Wairarapa Catchment Board intervened. Such systems are known as blind estuaries or estuarine lagoons

(Dyer 1986, Bird 1976). Estuarine lagoons often have three zones within them:

(1) Fresh water close to mouths of rivers,

(2) A salt water tidal zone close to the entrance,

(3) An intervening zone of brackish relatively tideless water.

Those cut completely off from the sea are essentially freshwater lakes (Bird 1976).

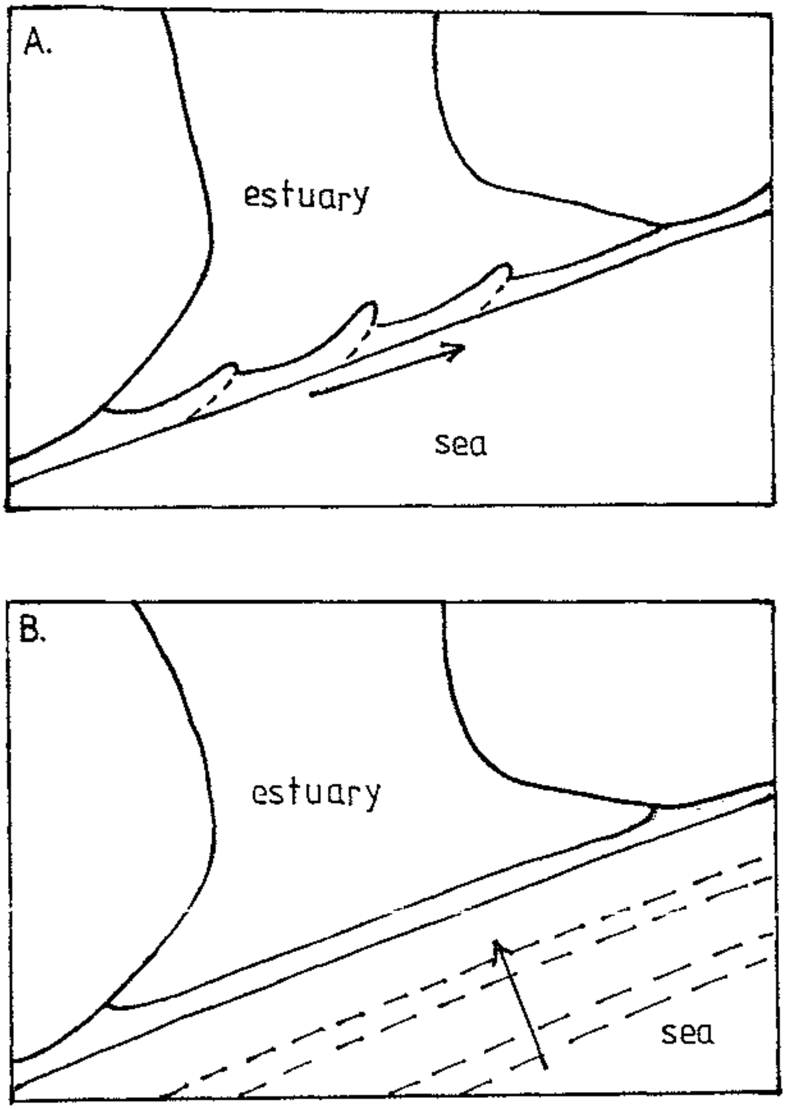


Figure 14 Two methods of bar development.

Estuaries may become enclosed by the development of a spit as in A above, gravels transported by longshore drift. They may also be enclosed by the shoreward migration of an offshore barrier as in B (from Bird 1976).

2.3.2 The oldest dune-line.

The oldest, outermost dune-line is often preserved above cliffs cut by the maximum sea- level 6 500 years ago (Palmer 1982). The dune-line extends south-westwards from an area just south of the Tauherenikau River, to the area south-east of the junction between the Ruamahanga River diversion channel and the channel draining Lake Wairarapa (figure 4). A maximum height of 43 metres is reached by the dunes in the vicinity of Kahutara, falling to approximately 20 metres at each end of the dune-line (see map of soil description sites). On the map of late Quaternary deposits the dune-line is placed in unit 1 in which sands are found to a depth of more than 90 centimetres.

Jennings (1967) found in his studies at King Island, that active coastal dunes have no difficulty in climbing cliffs and building extensive dunes on top (figure 15). The most important prerequisite is the formation of a beach and dunes at the foot of the cliff.

Sand could have been supplied to the foot of the cliff by a variety of methods.

(a) Transportation of unconsolidated sediments from the inner shelf by the marine transgression.

(b) Transportation of sandy material from beaches and the offshore zone through the mouth of the estuary by tidal currents, then redistributed by flood tide currents.

(c) Reworking of sandy sediment deposited by the two rivers in mid-estuary by strong flood tide currents.

(d) Deposition of sandy sediments by the rivers at their entry points (i.e. delta formation).

It is likely that a combination of (b) and (d) provided the sandy beaches necessary for dune formation, and that the Ruamahanga River supplied much of the sand required.

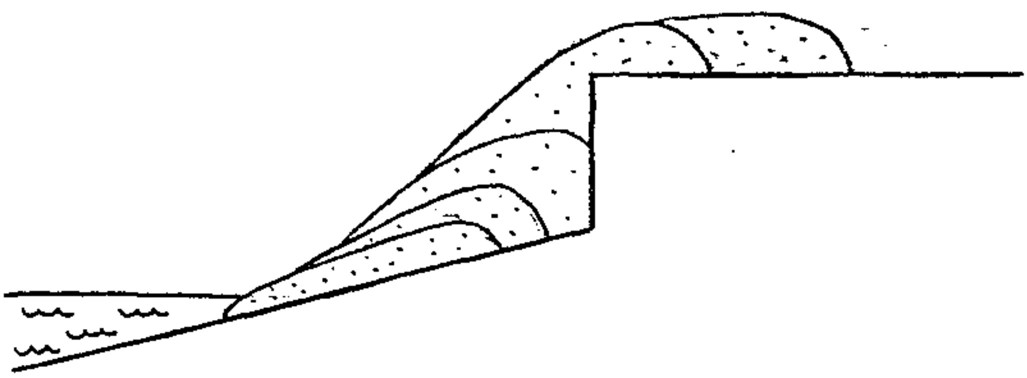


Figure 15 A method by which dunes climb cliffs.

Given the presence of a sandy beach and dunes at the foot of a cliff, active dunes have no trouble climbing cliffs and depositing dune sand on the top (from Jennings 1967)

2.3.3 Theory and discussion of delta formation.

A delta will form if the sediment accumulating at the river mouth exceeds that carried away by waves and currents. They form when a river enters an estuary or lake and the velocity is abruptly checked and competence drops. All bed load and most suspended load is dropped close to the point of entry and as the sediment accumulates the stream must extend its channel across the accumulating alluvium. The resulting landform is a delta. They are mostly subaqueous forms, although their upper surfaces are usually slightly above water level (Bird 1976, Bloom 1978).

Delta shape is determined by sediment supply and the action of waves and currents. Lobate deltas form where fluvial sediment is abundant and wave and current action is not strong. The simplest deltas are those built by rivers entering lakes, some consisting of a single river mouth flanked by depositional land (Bird 1976). A cross-section of these simple deltas shows three basic units:

(a) Almost horizontal bottomset beds,

(b) Inclined foreset beds (10-25°),

(c) Horizontal topset beds.

(Bloom 1978, Bird 1976).

The foreset beds are the thickest, thinning into the topset and bottomset beds respectively (figure 16)(Dyer 1986).

There are two broad environments on active deltas. One is the delta front comprising of the distributary mouth, areas of effluent discharge, tidal channels and lagoons. The second, the delta plain is the subaerial portion of the delta with its channels, marshes, backswamps and lakes (Leeder 1983).

Flooding occurs periodically on the delta plain and around the lower reaches of meandering rivers with gentle gradients. Flood waters may take weeks to recede back into the channel from the broad flood plains (Bloom 1978,

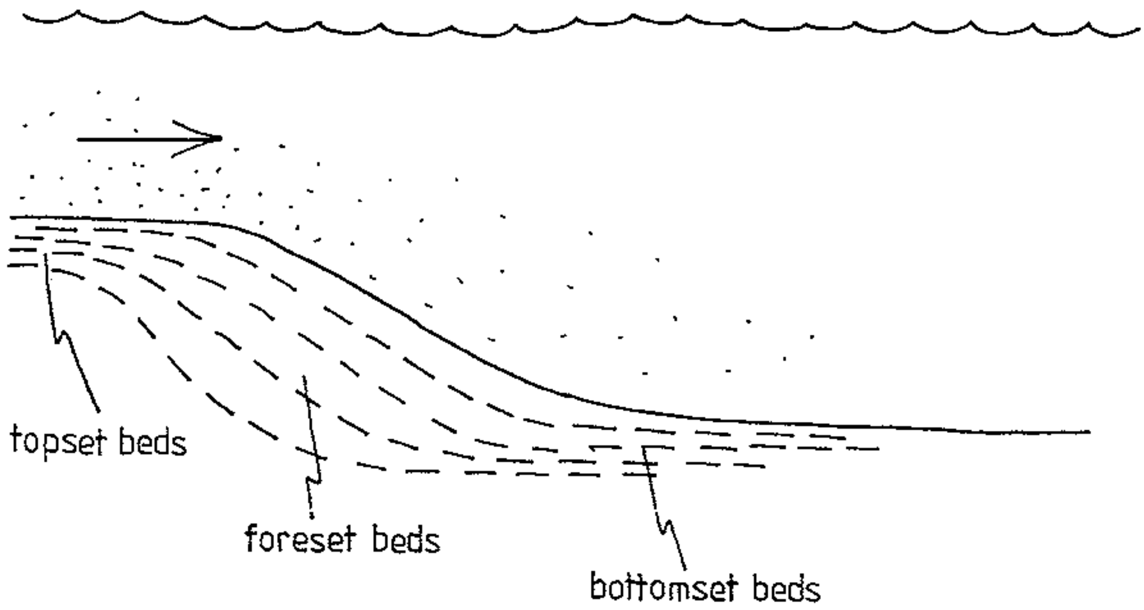


Figure 16 Cross section through a simple delta.

The development of a simple delta front showing how the thicker, inclined foreset beds thin into the bottomset and topset beds (from Dyer 1986)

Leeder 1986). Newly deposited sediment is acted on by soil forming processes. However well marked horizonated soils are generally poorly developed in areas of active floodplains because of the rapidity of sediment deposition.

ENTRY POINTS OF THE RIVERS.

Both the Ruamahanga and Tauherenikau Rivers carried large amounts of sediment to the estuary, depositing it at their entry points to form deltas. The Tauherenikau River would have entered the estuary in the same area that it enters Lake Wairarapa today, albeit further back. The Ruamahanga River would have entered the estuary close to Kahutara after flowing round the end of the Te Maire Ridge. Just south-west of Kahutara is a breach in the dune-line which indicates the entry point of a river. A present day tributary of the Ruamahanga River, the Dry River which drains part of the Aorangi Range, would have joined the Ruamahanga a short distance from where it flowed into the estuary.

River discharge, and therefore sediment discharge may be seasonally variable with considerable variation around the annual mean. It is common for most sediment discharge and sedimentation to occur in occasional extreme events (Dyer 1986).

STONY DEPOSITS OF THE RUAMAHANGA RIVER DELTA.

An interesting feature is found approximately one kilometre west of the breach in the outermost dune-line, around the junction of Judds Road with Kahutara Road (see Late Quaternary Deposits map). In this vicinity stony deposits are found, commonly interbedded with sands and grits. Such coarse textured sediments are unusual, all other deposits within the study area are finer than grit, and generally finer than coarse sand. This indicates that even in flood the Ruamahanga River does not usually transport material much larger than coarse sand.

The stony sediments are found mainly in unit 6 (less than 45cm of silt over sand and gravels). The unit is described in detail in section 2.2.2.

A sketch diagram showing depth to stones did not provide much information as the depths are highly variable over short distances. River flood plains have a similar pattern with gravel bars and silt filled channels, the depth to stones changing rapidly over short distances. Gravels found at the surface may only extend to a depth of less than half a metre before resting on sand, complicating any interpretation of a diagram showing their initial depth.

A diagram of the continuity of the stony layers was drawn to see if any pattern could be found (figure 17). The definition of the categories are somewhat subjective (what is a thin layer?), but serve to show general trends. Figure 17 shows that the continuity of the stony layers decreases westwards with increasing distance from the junction of Judds Road and Kahutara Road. The zones of decreasing abundance are roughly semi-circular about the junction, though skewed towards the backwater between Judds Road and Wharetoto Road. From the distribution and continuity of gravel layers it appears that they were deposited by the Ruamahanga River after it flowed through the breach in the dune-line. Therefore they would have been part of a former delta.

Currently the Dry River which drains the shattered belt of the Dry River Fault delivers shingle to the Ruamahanga River (Kite 1952), and is probably the source of the gravels in unit 6. As the Ruamahanga River does not usually deposit such large material (even in flood), it seems that an extremely large flood event would be required to account for the deposition of gravels over a zone up to two kilometres wide and two kilometres long. Such an extreme event could well be the same one as cited by Leach and Anderson (1974) to explain the sudden death of estuarine shellfish in the Kumenga and Birchwood areas, approximately five kilometres south of the study area. The shellfish were buried *in situ* by non estuarine silts *circa* 3 500 years ago.

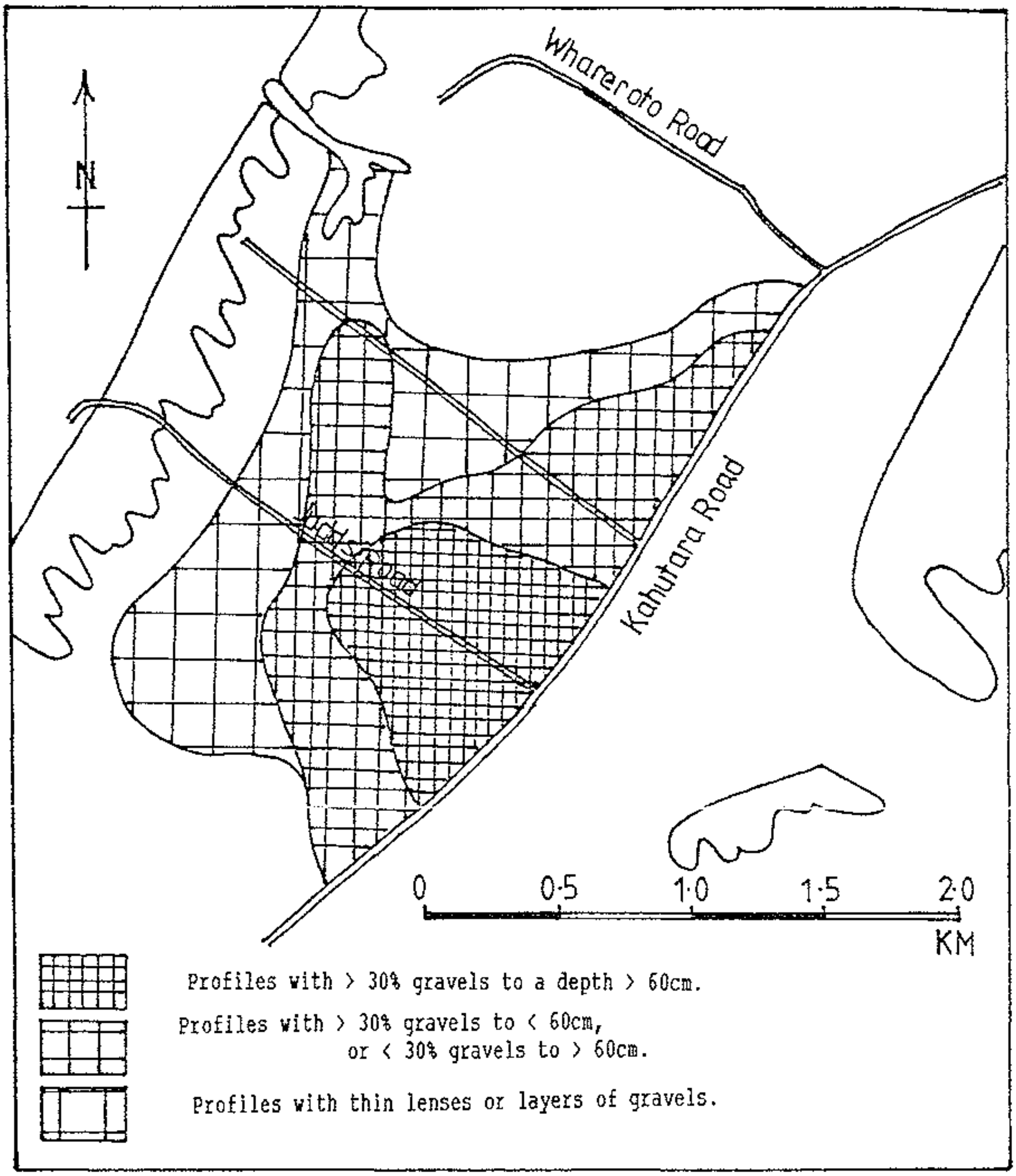


Figure 17 The abundance and distrubution of gravels.

The abundance of gravel, and the thickness and continuity of layers, decreases with increasing distance from the junction of Judds Road with Kahutara Road. The lobate distribution of the gravels suggests deposition in a deltaic environment. No profiles were examined between Kahutara Road and the breach in the outermost dune-line.

A large storm delivering a large volume of precipitation to the Wairarapa Valley could produce such an event. If enough rain fell in the Eastern hills or Tararua Range the Ruamahanga River would be in flood and therefore able to transport gravels from its junction with Dry River to the estuary. A high rainfall in the Aorangi Range would cause water levels in the Dry River to rise, and thus its shingle carrying capacity. The Paharakeke Stream and the Whangaehu Stream would also be in flood and able to carry large amounts of sediment. The two streams discharged into the estuary above Leach and Anderson's Birchwood and Kumenga sites respectively.

The type of storm required to produce such an event need not be a prolonged one. Rainfall of short duration but high intensity is very effective at raising river levels, especially after a few days of drizzle and/or showers to saturate the soils in the area. High intensity rainfall is more likely to lead to erosion and therefore high sediment loads in rivers.

As can be seen from figure 17 and the maps of Late Quaternary Deposits and Physiographic Units, the stony deposits form only a part of what is now an alluvial plain. The stony sediments of unit 6 grade into the sediments of unit 8 to the north-east and unit 7 to the south-west. The latter units contain more than 90 centimetres of silt over sand, and between 45 and 90 centimetres of silt over sand and grits and/or gravels respectively. They are described in more detail in section 2.2.2.

The gravel layers of unit 6 are found under, over and between sandy layers which may contain silt lenses. Sediments within the stony unit appear to interfinger with sediments from the adjacent units. This infers that a delta was already forming in front of the dunes. The material deposited by the large storm event may have been reworked by estuarine and delta currents, as subsequent deltaic deposition took place on and around the coarse gravelly material.

CROSS SECTION THROUGH THE OPORUA FLOODWAY.

The Oporua floodway provides a natural cross-section through the southern end of unit 7, and the dune-line that borders its western edge (plate 3). Sediments near the second dune line were well exposed and so able to be recorded (figure 18).

The profiles to the east of the second dune-line are similar to that described at Kumenga by Leach and Anderson (1974) (figure 11). Blue-grey estuarine sands with a sandy loam texture are overlain by grey and orange/brown coloured silts and sands. At the interface between these sediments is a layer of organic material composed of many leaves, seeds and twigs, similar to that found at the top of the estuarine sands at Kumenga. A radiocarbon date from a sample of the leaves from Oporua dates them at 3 660 ± 60 years B.P. Above the silt and sand layer is one of sands and grits which may be massive or cross bedded (plate 4). These are the sands and grits at the base of unit 7, overlain by fine sands and silts. Ahikouka silty clay loam on sand soils have developed in the sediments of unit 7, and are described in chapter three. Profiles exposed by drains, and flood scouring show that the basic pattern of blue-grey estuarine sandy muds topped by organic material, overlain by fine sands and silts which may contain alluvial gravels is repeated throughout the whole of unit 7.

To the west of where the dune has filled in a former channel, the blue-grey estuarine sandy mud and associated organic material is overlain directly by iron stained sands and grits. This coarse layer has internal bedding which dips to the west and would be the foreset beds of the former delta. The soil Ahikouka silty clay loam on sand has also developed on these sediments, but is buried by a thin layer of trailing dune sand, proving that the dunes moved across the delta plain quite a long time after it had formed. Further to the west the soil Ahikouka silty clay loam on sand dips to the west and is covered by recent deposits of structureless sand which has both low chroma and ochreous mottles (plate 5). The buried topsoil no longer

Plate 3 Oporua floodway

This photo of the lower part of the Oporua floodway, taken from dune line two, shows the flat swampy nature of the land. The Oporua waterway is probably a previous course of the Ruamahanga River.

overlies grits and sand but a clayey layer containing many small iron pipes, which in turn overlies the estuarine sands. Iron pipes typically form around plant roots which extend through a reduced zone such as a gley layer. Thus the clayey layer probably represents a narrow zone of intertidal mud flats at the margin of the delta. Intertidal flats often form within estuaries and grow a range of salt tolerant (halophytic) vegetation.

The similarity of the eastern part of the cross-section to the profile described by Leach and Anderson at Kumenga confirms that the catastrophic event which buried and killed the shellfish is the same event that deposited the gravelly deltaic fan just south of Kahutara. Leach and Anderson (1974) have dated the occurrence of this event at approximately 3 500 years B.P. As the soil developing in the then still accumulating delta, was subsequently buried by the dune sand of the second dune-line, these dunes must be somewhat younger than 3 500 years.

With increasing deposition deltas grow upward and outward, causing rivers to change their course in order to obtain sufficient gradient. The Mangatete Stream, the waterway in the Oporua floodway and the backwater between them probably represent large deltaic channels occupied by the Ruamahanga River as it flowed out into the estuary. At some point in time the Ruamahanga River changed its course considerably, entering the system at a more southerly point. The change may have been caused by the pattern of deposition within the delta, or possibly induced by the effects of an earthquake. The new point of entry of the river was in the vicinity of the junction of Kahutara Road with the East-West Access Road (see Late Quaternary Deposits map).

SILTY DEPOSITS OF THE LATER RUAMAHANGA RIVER DELTA.

At it's new entry position the Ruamahanga River started to build out a new delta. The deltaic sediments are described in section 2.2.2, and are units 3, 4 and 8 on the accompanying map. These units contain less than 45 cm of silt over layered sands and clays, between 45-90 cm of silt over layered

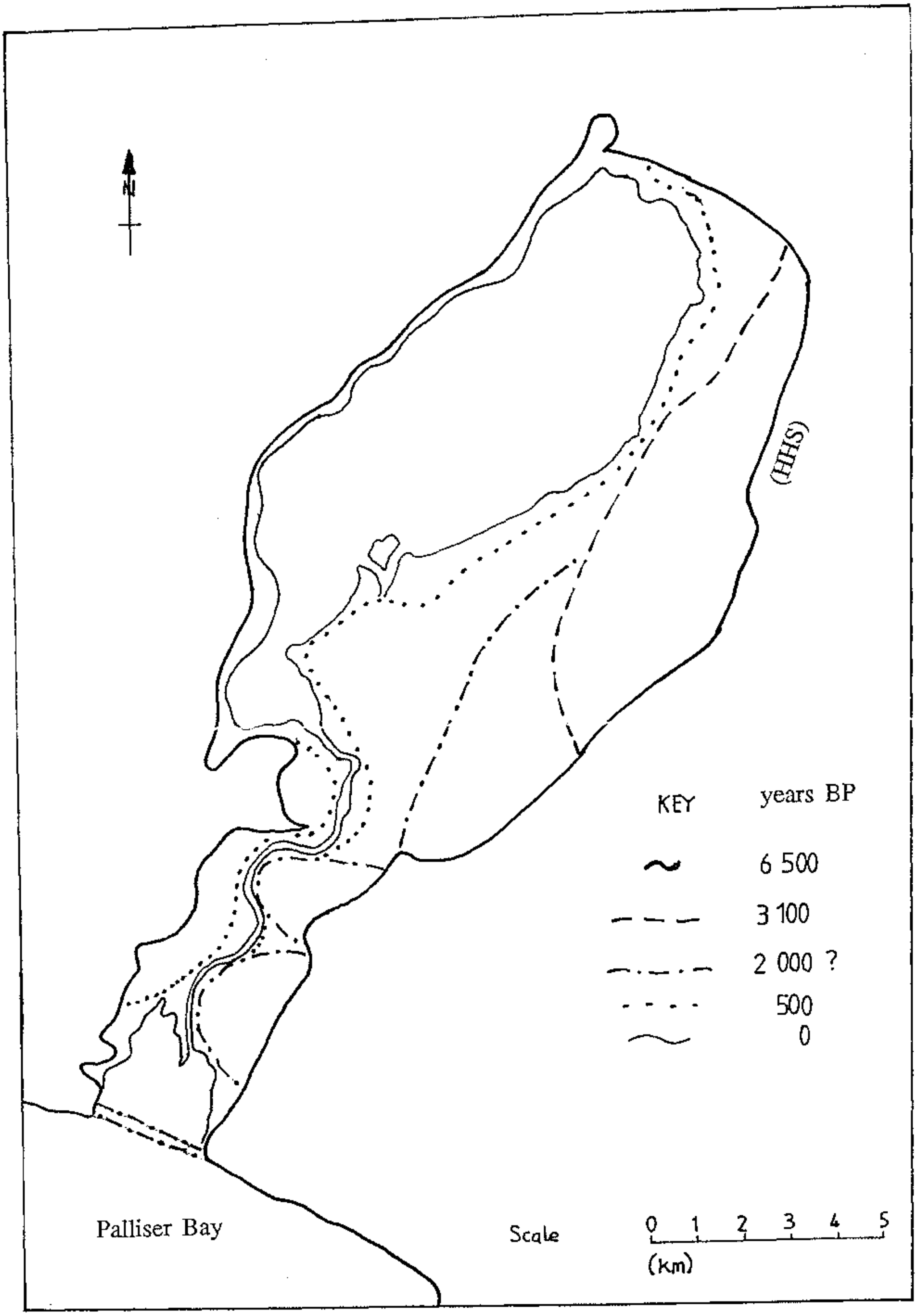


Figure 28 Changing shoreline positions recorded on the eastern side of Lake Wairarapa.

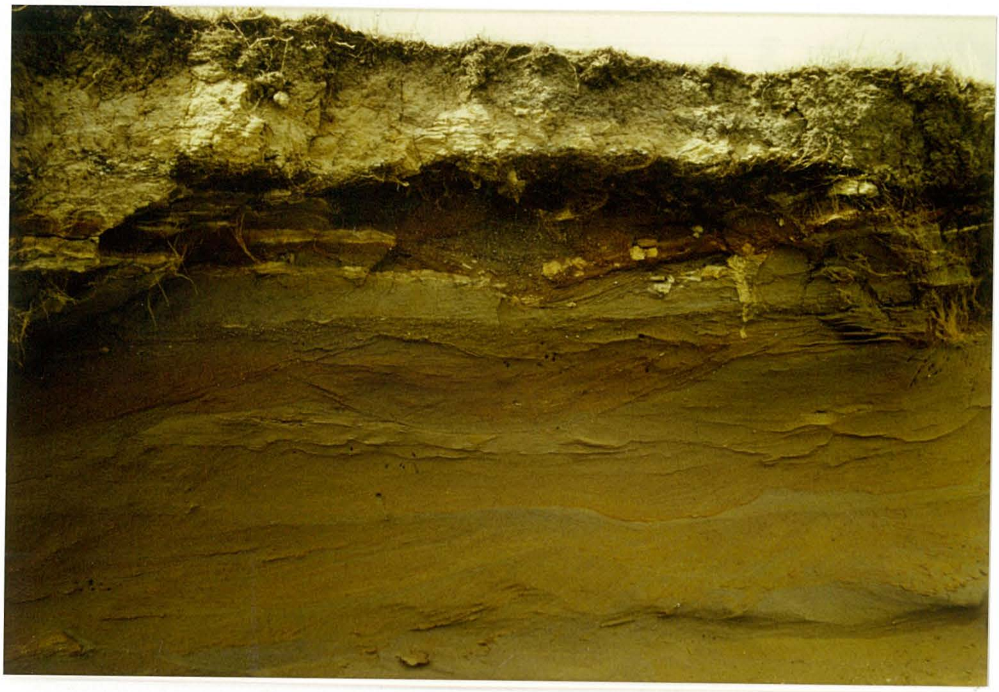


Plate 4 Cross bedded sands and grits in the Oporua floodway.

Pictured above is a thin layer of silty sediment overlying cross bedded coarse sand and grits. The section lies a few hundred metres east of the second dune line, and would have been part of the initial delta formed by the Ruamahanga River.

Plate 5 Buried soil in the Oporua floodway.

The soil Ahikouka silty clay loam on sand is formed in the deltaic sediments of unit 7. West of dune-line two the soil surface dips westward and is buried by structureless sand. In places, iron pipes' are common in the subsoil below the buried topsoil.

sands and clays and more than 90 cm of silt over sand respectively. The deltaic sediments are much finer than those of the previous delta, and this along with the lobate shape indicates that they have been deposited in a lacustrine rather than estuarine environment. The delta was active until 1968 when the Ruamahanga River was diverted, all normal flows prevented from entering Lake Wairarapa (Pickrill and Irwin 1978). That the floodplain was active until recently is shown by the poorly formed soil profiles.

In gently shelving basins (such as Lake Wairarapa) the frictional effects of bottom drag on the incoming jet of water and sediment are very important. Where jets are strongly influenced by friction they quickly deposit a 'mid-ground distributary mouth bar, bordered on its margins by a Y-shaped channel bifurcation, (Leeder 1983). A mid-ground distributary mouth bar has developed where the Ruamahanga River formerly entered the lake. The bar is above water at normal lake levels and is known locally as Jury Island or Willow Island (figure 19).

The subaqueous delta front and the subaerial delta plain are both well described (see section 2.2.2, Pickrill and Irwin 1978). According to Pickrill and Irwin (1978) the morphology and sediments of the Ruamahanga delta conform to classical concepts of deltaic sedimentation, having a prograding convex deltaic form with low angle topset slopes and steeper foreset slopes. A thin sheet of sands overlies deltaic muds.

2.3.4 Theory and discussion of dune formation.

Periodic dune formation associated with progradation has occurred several times on the eastern shore of Lake Wairarapa.

There are three main requirements for the formation of sand dunes:

(1) An abundant supply of sand,

(2) Common strong onshore winds,

(3) Exposure of the sand to the wind.

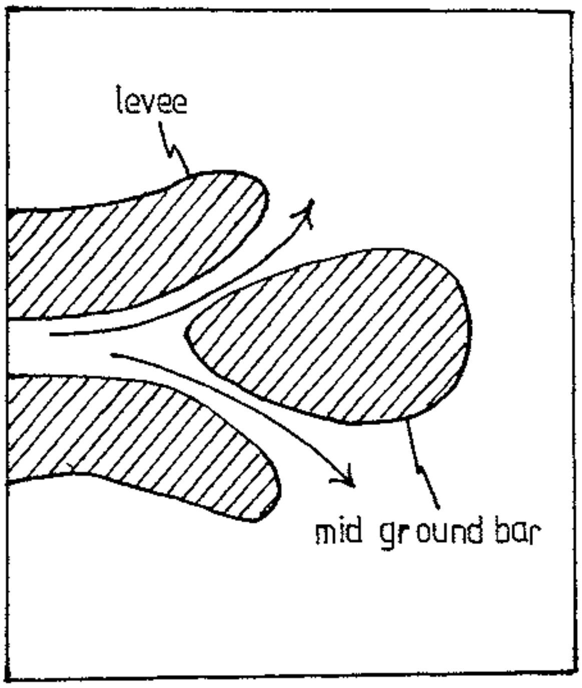


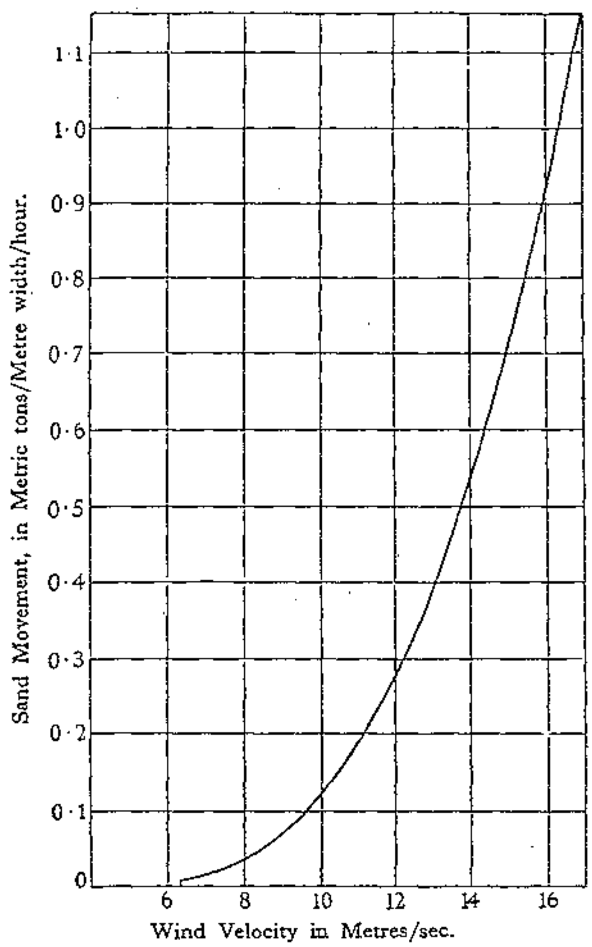
Figure 19 Mid-ground bar development

Mid-ground distributory bars form in shallow basins where the incoming jet of sediment and water are strongly influenced by the friction of bottom drag. The island at the mouth of the Ruamahanga delta formed in this way, and its outline is very similar to the diagram above.

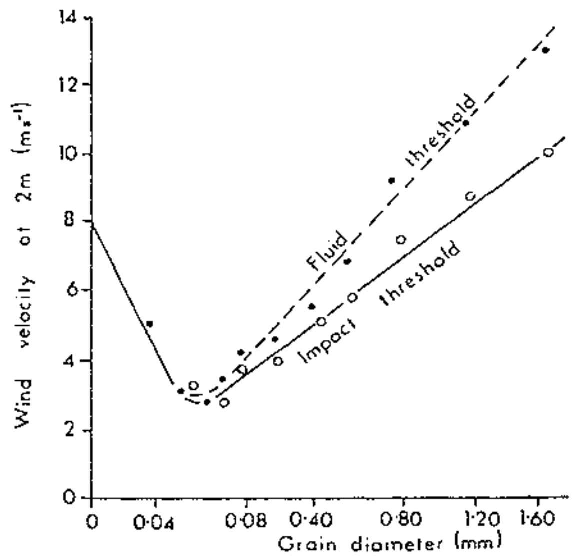
Thus large dune complexes are likely to occur where there is an active sand supply, impeded littoral transport, strong onshore winds, low precipitation and humidity, low beach face angles and low tidal ranges. Aeolian sand transport rates are potentially highest on wide low angle beaches (Davies 1980, Pye 1983). The three main requirements are met on the eastern shore of Lake Wairarapa. There are frequent onshore winds from the north-north-west and north west, and the Ruamahanga River has delivered large quantities of sand, first to the estuary, then to the lake. Salt wedge estuary circulation ensured that sandy material was moved landward, and once Lake Wairarapa formed the large deltaic sandbanks developed. The sandbanks have a gradient of less than 0.01 (Pickrill and Irwin 1978), and are exposed at least annually for several months during low summer lake levels.

The wind needs to blow above a certain threshold velocity to move sand, and for medium sand the velocity which is just strong enough to set the grains in motion is approximately five metres per second (Bagnold 1960). Sand transport varies as the cube of the excess of wind velocity over the threshold velocity, $(\text{wind velocity - threshold velocity})^3$. Sand movement increases very rapidly with wind strength (figure 20), and it is generally considered that the most effective sand moving winds are those of Beaufort scale three and over. Thus storm winds of even short duration are significant (Davies 1980, Bird 1976, Pye 1983). If sand is moist the threshold velocity is increased considerably, the first two percent of moisture content being particularly important. Sand which has been dried by exposure to sun and wind is much more easily moved.

Beaufort scale 3 is equivalent to a wind speed of seven to ten knots. Mean monthly wind speeds in locations around Lake Wairarapa range from a low of eight knots to a high of sixteen knots, with winds of over 30 knots blowing approximately four percent of the time (Thompson 1982). It has been noted by the Wairarapa Catchment Board and Regional Water Board (1985) that the drying out of the sand flats commonly leads to the occurrence of sand storms.



The relationship between the wind velocity at a height of 1 metre and the flow of average dune sand (from Bagnold 1960).



The relationship between critical wind velocity at a height of 2 metres and mean grain size of quartz sand (from Pye 1983).

Figure 20 Wind velocity and sand movement.

When set in motion by the wind, sand grains move in one of two ways. Approximately three-quarters moves via saltation, about one-quarter by surface creep. Once a grain has been picked up by the wind it moves in a curved path, gaining energy from the wind until it strikes the ground at an angle of 10-16°. A portion of the energy acquired by the grain from the wind is passed on to grains which it strikes, ejecting them in turn upwards into the wind. Saltating sand rarely rises above one metre, and the average height reached is approximately ten centimetres. Much of the energy of the saltating sand is dissipated in disturbing a large number of surface grains, knocking them forward rather than upward. This process is known as surface creep. The wind velocity required to initiate sand movement by lift or shear (fluid threshold velocity) is always higher than that required to maintain movement by ballistic bombardment (impact threshold velocity), (figure 21), (Bagnold 1960, Pye 1983).

Primary dunes form where sand deposited on the shore dries out and is blown to the back of the beach by the wind, and is colonised by vegetation. The foredune is a typical primary dune, forming parallel to the rear of the beach. High foredunes are found on coasts which are stable or slowly prograding (Bird 1976, Davies 1980, Pye 1983).

Transgressive dunes are aligned in the direction of the most common strong winds and form where the vegetation of unconsolidated foredunes is destroyed or removed, no longer holding the sand in position. Vegetation may be removed by burning, overgrazing, aridity, or storm waves cutting away the front of the dune, leaving a cliff of loose sand (Bird 1976). There are a variety of forms of transgressive dunes (Davies 1980).

Parabolic dunes (U dunes) develop where the source dune is no longer receiving new sand. The blowout migrates with an advancing nose of loose sand, and trailing arms of partly fixed vegetated sand. As the dune travels the sand at the head of the dune is progressively exhausted and the two

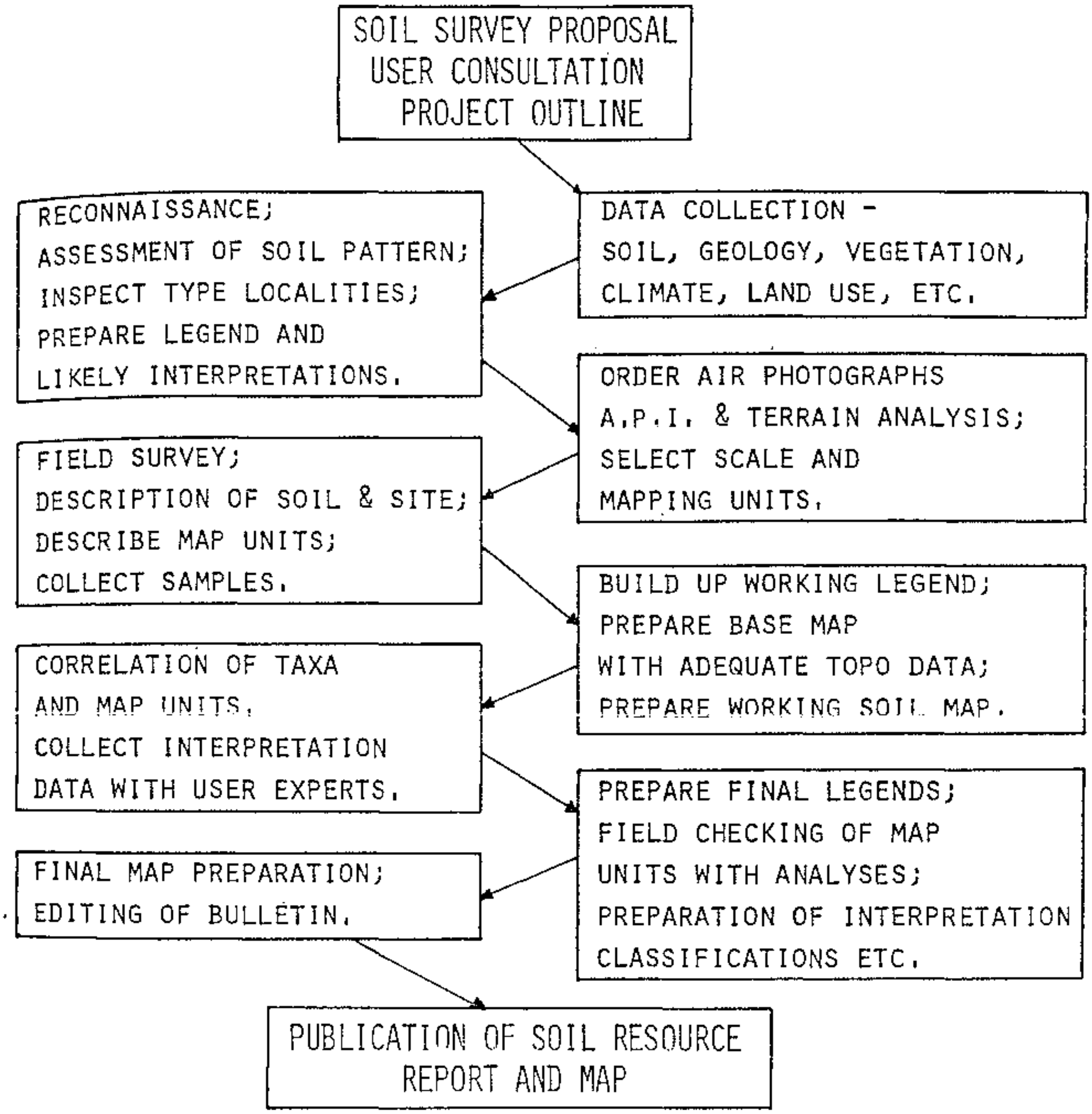


Figure 21. FLOW DIAGRAM SHOWING STAGES IN PREPARATION OF A SOIL RESOURCE SURVEY.

trailing edges develop into long slightly converging ridges. The axis of each parabolic dune is parallel to the resultant vector of onshore winds of Beaufort scale three and over, and it is defined as the line bisecting the angle between the trailing arms (Bird 1976, Davies 1980).

In humid environments on shores which are stable or prograding, a temporal and spatial dune succession is often found. Older, more landward dunes are stabilised under increasingly complex vegetation communities, and have progressively better developed soils. Generally dune activity decreases with increasing distance from the shore (Pye 1983).

The three main requirements for the formation of parabolic dunes are:

(1) time,

(2) frequent high velocity winds from one direction,

(3) a large flattish area to the rear over which sand can be moved.

If there is a variation in the direction of strong winds, parabolic dunes remain massive with high width/length ratios. Transgressive sheets form where enough sand is freed for blowouts to coalesce (Davies 1980).

The dune-lines along the eastern shore of Lake Wairarapa show parabolic outlines (see physiographic units map). Axes of the parabolic dunes lie between the angles of 300° and 330° (Heath 1979). These correlate well with the direction of the onshore north-north-west and north-west winds.

THE SECOND DUNE-LINE.

Parabolic dunes develop from unconsolidated foredunes which would have formed on slowly prograding or stable delta front shores. Thus dune-line two on the earlier stony delta formed as the Ruamahanga River moved southwards with time. The height reached by dunes within the second dune-line is at a maximum between Oporua floodway and Mangatete Stream. Height falls dramatically to the south-west. This suggests that the dunes to the south did not have as much time in which to form.

Although the delta plain behind the parabolic dunes is very flat, they do not extend very far across it. One reason for this would be that the delta plain was frequently flooded, the floodwater taking weeks to recede. As sand cannot saltate across water (or even very wet surfaces), and few grains travel long distances in the air, water is an effective barrier to dune movement. Colonisation of the dunes by vegetation would start to stabilise them, leaving them less prone to movement when dry conditions returned.

PARABOLIC DUNES OF THE MORE RECENT DELTA.

The parabolic dunes extending south-eastwards across the more recent, finer textured delta, originate from foredunes only about half a kilometre away from the present lake margin. Over much of the delta plain there are no dunes, with the exception of a few isolated fragments of a low foredune (<1 metre high), found approximately halfway across.

The lack of dunes indicates that either the delta was prograding too rapidly for dune formation to take place, or that there was a lack of sand sized material available to form into dunes. As the Ruamahanga River was discharging its sediment into a lake/lagoon system rather than an estuary, fine material was no longer being swept out seaward, but deposited as part of the delta. The resulting large increase in the proportion of fine material to sand sized material could be responsible for inhibiting the formation of dunes. The main requirements for the formation of dunes are the exposure of a large supply of sand to frequent onshore winds. These requirements would not be met if the amounts of fine material being deposited led to the formation of mudflats rather than sandflats at the delta front.

It was probably during this period of relatively rapid progradation that the Ruamahanga River deposited sediment across the southern end of the embayment, helping separate Lakes Onoke and Wairarapa.

The formation of dune-line three may be related to the activities of the early Maori settlers, and their impact on sedimentation in the area. Leach (1981) studied the prehistoric Maori settlement patterns in the southern Wairarapa. The early Maori population mainly occupied the coastal area, and the valleys of rivers entering Palliser Bay (Leach 1981). Evidence of occupation is also found in the valleys of the Turanganui and Tauanui Rivers, both of which flow into the Narrows.

During the period 1250-1450 AD the number of birds being caught declined, and was attributed to the significant encroachment of garden areas into the forested hillsides of the Aorangi Range. This was followed in 1450-1550 by the disappearance of filter feeding shellfish, due ultimately to slope erosion caused by deforestation. During this time the rivers were carrying high sediment loads. If forest burning was the common clearance method, it is quite possible that large areas were burnt, and that the catchments of rivers which feed the Ruamahanga, such as Waihora Stream and Dry River were also affected.

Leaches summary of climatic change (figure 6) shows that the climate slowly deteriorated from about 1400 AD. The 'little ice age' began soon after 1600 AD, causing the local Maori population to leave the area. The New Zealand speleothem curve (figure 6) indicates warming in the area from approximately 1750 AD. Thus from approximately 1400 -1450 AD the effects of deforestation and climate deterioration combined to increase the sediment load of streams and rivers.

Severe erosion in the occupied valleys of rivers entering Palliser Bay led to the formation of braided rivers and shingle beaches. High sediment loads in the Turanganui and Tauanui Rivers at this time would have allowed them to form small deltas that would help separated Lake Onoke from Lake Wairarapa, and push the lower Ruamahanga River to the western side of the Narrows.

The tributaries of the Ruamahanga River which drain the Aorangi Range, Dry River and Waihora Stream, would also have transported an increasing amount of coarser material. This would have the result of a larger proportion of sandy sediments being carried by the Ruamahanga River, and therefore deposited at the delta front. This material could then be blown into foredunes from which parabolic dunes could form.

A peat lense found at site B, near the edge of an ephemeral pond to the east of dune-line three, was sent to be radiocarbon dated. The sample was dated at 590 ± 50 years B.P. Thus the silty clay sediments which underlie the peat, and represent the surface of the delta plain were deposited before this date, and the overlying sand and sandy clay loam after. The fining upwards sequence of the sediments overlying the peaty layer is typical of deltaic sediments, and were possibly laid down 400-500 years ago when the Ruamahanga River started to carry more sandy sized material.

The foredune which was the precursor for the parabolic dunes of dune-line three, formed to the west of the peat, overlying similar material to that which buries it. They must therefore be younger than the peat. Parabolic dunes up to two kilometres in length extend from the original foredune of dune-line three. Movement of the sand may have been initiated by storm waves cutting into the foredune. It is more likely that the stabilising vegetation was disturbed by the later group of Maori settlers who occupied the Wairarapa Valley.

The sand-dunes at the lake margin, which form dune-line four, are probably linked to clearance of native vegetation by European settlers.

2.3.5 Formation of the Onoke gravel bar.

At some stage during the infilling of the Wairarapa estuary, the Onoke gravel bar formed across the seaward entrance of the Narrows (plate 1), and the system became a blind estuary (see section 2.3.1). As the bar could only be breached by the pressure exerted by high water levels, it would have remained closed throughout most summers. Fine sediments were no longer carried out to sea all year round. Instead they were deposited within the basin, eventually separating Lake Onoke from Lake Wairarapa. Leach and Anderson (1974) consider that the rapid deposition of silts over estuarine sands in the Kumenga area 3 500 years ago signals the change from an estuarine to a lacustrine environment.

Stevens (1973) described the formation of gravel bars across the mouths of two drowned valleys immediately east of Pencarrow Head. The inlets were initially cut off from the sea by the formation of shingle spits, and eventually by gravel bars widened by uplift in the 1460 and 1855 earthquakes. The gravel bars have impounded fresh water behind them creating Lake Kohangapiripiri and Lake Kohangatera (Stevens 1973, Stevens 1974b).

The gravel bar across Lake Onoke would have formed in a similar way. Gravels supplied to the coast from the greywacke ranges and transported by longshore drift would have built the initial shingle spit. This would form a base that waves could then throw gravels and sand over and onto, especially storm waves. Eventually the spit grew large enough to be able to completely block the entrance, probably widened by the earthquake about 3 100 years ago which uplifted beach ridge D at Turakirae Head (see section 2.1.1).

2.4.0 Physiographic units of the study area.

The physiography of the land is the description of those geomorphic features which are of significance to the soil and its uses (and includes the relief factor of soil formation). (Cutler 1977).

There are two main physiographic units recognised in this survey; both are subdivided into a number of units.

(1) The sand dunes

(2) The alluvial plains.

2.4.1 The sand dunes.

The dune lines along the eastern shore of Lake Wairarapa provide the only relief in an otherwise low lying, flat to easy rolling landscape.

Some of the dunes form coherent lines which are easily recognised. Others are scattered over the low lying plains allowing the interpretation of a varying number of dune lines.

DUNE SETS 1 - 4.

In this survey, four dune lines were recognised. These were delineated on the basis of aerial photograph interpretation and the field examination of such features as soil profile development. The dune lines were numbered one to four in the order of development, i.e. from oldest to youngest (see accompanying map - Physiographic Units). Each dune line is considered to form a separate physiographic unit. Whether or not they are part of an easily recognised dune line many dunes have been blown by the wind into hairpin or U shapes, common forms of transgressive dunes (Davies 1980).

2.4.2 The alluvial plains.

SAND BANK.

The broad flat sandbank forming the eastern shore of Lake Wairarapa is considered to be a physiographic unit (see accompanying map - Physiographic Units). It is frequently flooded by high lake levels, especially in winter months. Vegetation manages to grow through the summer when the sandbank is more often exposed continuously for long periods of time. Even then vegetation is sparse and is found only on the half of the sandbank closest to land.

RAPIDLY ACCUMULATING FLOODPLAIN AND LAKE MARGINS.

The extensive low lying areas around the former Ruamahanga River channel and behind the sandbank are grouped together into one physiographic unit (see accompanying map -Physiographic Units). These surfaces generally have an elevation equalling or less than four metres, and are flat to easy rolling. Before the diversion of the river they would have flooded at least annually, and up to an estimated eight times a year. Apart from the sandbank, this unit would be the first to be flooded at times of high lake levels. The low gradients of this physiographic unit mean that water doesn't run off quickly into drainage channels but ponds on the surface for days at a time. Parts of the unit pond water for long periods in winter (see plate 33) due to the poor internal drainage of some of the soils present, and the high water table of those soils along the lake margin.

DRAINED AND EPHEMERAL PONDS.

Another physiographic unit is made up from the scattered shallow basins which are found within the rapidly accumulating floodplain and lake margins (shown enclosed by dashed lines on the accompanying maps). These are the bottoms of either ephemeral or artificially drained ponds, and have elevations of less than one metre. Apart from artificial drainage the only way water can drain out of these basins is through the underlying sediments, (commonly slowly permeable silts and clays). Because of the lack of natural drainage these areas tend to pond rainfall and associated runoff throughout winter months. To drain these ponds to claim the beds for pasture, water has had to be pumped out. Water is pumped to the Boggy Pond and Mathew's Lagoon wildlife reserves which are enclosed by stopbanks.

SLOWLY ACCUMULATING FLOODPLAIN.

The flat to easy rolling land between dune sets one and two forms another physiographic unit (see accompanying map - Physiographic Units). This area has a slightly higher elevation than the other floodplain, the area being between four and ten metres above mean sea-level. Gradients are still small and as the land drains moderately slowly, low lying parts pond water unless artificially drained.

PHYSIOGRAPHIC UNITS LEGEND
(to accompany the map in the back pocket)

- Dune set one
- Dune set two
- Dune set three
- Dune set four
- Slowly accumulating floodplain
- Rapidly accumulating floodplain and lake margins
- Drained and ephemeral ponds
- Sand bank
- ·3 Spot height (in metres above mean sea level)

CHAPTER THREE: SOILS.

3.1.0 The soil survey.

3.1.1 Introduction.

WHY MAP SOIL?

Soil surveys attempt to delineate the soil pattern of an area. Soils are mapped according to morphology on the hypothesis that soils which look and feel alike will behave similarly, and those that appear different will respond differently to some specified management. Each kind of soil is characterised so that responses to changes can be assessed and used as a basis for prediction (Taylor and Pohlen 1962, Dent & Young 1981).

Soil profiles record the effects of past and present environments, also historical events such as eruptions, erosion and floods. Successive groups of soils formed from sediments illustrate the development of soil profiles over increasing periods of time (Gibbs 1980). This means that as well as recording characteristics of soils which may be of importance for good management, and the delineation of soils of value for special purposes, maps can be produced to assess the risk of potential hazards such as flooding.

WHAT IS SOIL?

Before soil can be mapped there must be a definition of what is and is not soil. This enables the recognition of soil and allows its limits, both horizontally and vertically to be determined. Soil has been distinguished from the earth's crust from which it is formed as;

> 'the outer layer of the earth's land surface in and on which organic life exists, in contrast to the lifeless lithosphere which is the outer mineral crust of the earth.' (Taylor and Pohlen 1962).

There are many definitions of soil. Many stress both that it is a natural body which supports life, and the factors which collaborate to form soil;

> 'the collection of natural bodies occupying portions of the earth's surface that support plants and have properties due to the integrated effect of climate and living matter, acting upon parent material as conditioned by relief over periods of time' (Wilding, Smeck and Hall 1983).

This definition does not explain what soil properties are, or if they are the same everywhere, or vary in type and intensity from place to place. Soils have also been defined as;

> 'independent natural bodies, each with a unique morphology resulting from a unique combination of climate, living matter, earthy parent materials, relief and age of landform. The morphology of each soil, as expressed by a vertical section through the differing horizons, reflects the combined effects of the particular set of genetic factors responsible for its development' (Soil Survey Staff 1975).

Soils are living things. They are made up of not only lifeless inorganic and organic materials comprising the soil body, but also the living organisms within it, for instance bacteria, fungi, insects and plant roots. Thus soils are dynamic systems to which materials are added and removed, with seasonal and more long term changes reflected in the soil profile (Taylor and Pohlen 1982).

Because it is relatively stable, the soil body or inanimate part of the soil is the subject of most soil descriptions. Soils are described and identified by their profiles. These are commonly but not always differentiated into horizons, differing from the parent material in morphology, physical and chemical properties and biological characteristics. Horizons are formed by soil processes and occur in bands subparallel to the surface, usually having indistinct irregular boundaries. The boundary between soil horizons and the underlying geological material is also commonly indistinct. Most soils contain three master horizons:

- A, the topsoil, commonly characterised by the accumulation of organic matter, maximum biological activity, and removal of materials dissolved or suspended in water;
- B, the subsoil, characterised by structure which differs from that above and below, and commonly by accumulation of materials carried down from A;
- C, the underlying parent material

(Taylor and Pohlen 1962, Gibbs 1980).

3.1.2 Soil mapping.

There are many stages involved in producing a soil map. These are summarised in Fig 21 (Cutler 1977).

There are two main types of surveys: ad hoc surveys which are done for specific purposes such as suitability for irrigation, and multipurpose surveys with the objective of recording the soil as a basic resource which can be interpreted for any likely use (Cutler 1977). This is intended to be a multipurpose survey, the soils being mapped at the scale of 1 : 25 000. This is the scale of both the aerial photographs used in the field to locate soil profile description sites, and the base map on which sites and boundaries were recorded. It is a useful scale as individual fields are able to be identified, even though whole farms are shown. At this scale the area represented by $1cm^2$ is 6.25 hectares.

LOCATION AND DESCRIPTION OF SOIL PROFILE SITES.

During soil surveys many soil profiles are described and grouped into a number of different soils delineated on the map by boundary lines.

LOCATION OF SITES

There are three main techniques of determining the sites for the description of soil profiles. These are the free range method, the pace and compass line traverse method and the grid method. Any or all of these methods, or some compromise between them may be used in a survey.

FREE RANGE METHOD

This is the most common method of soil survey where the use of aerial photographs and ground evidence, such as topography, fencelines and trees, allow the location of observation sites to be determined. Description of soil profiles are made at representative sites which will provide the maximum amount of information. The density of observations is not predetermined, and can therefore be adjusted to suit the complexity of the soil profile (Cutler 1977, Dent and Young 1981). It is the method used in this study, the use of aerial photographs allowing the accurate location of description sites.

PACE AND COMPASS LINE TRAVERSE

This method is used where aerial photographs do not aid in the plotting of soil boundaries, i.e. under forest, in swamps, or on flat featureless plains. In these situations the only way to accurately determine the position of observation sites is by measurement. Descriptions are made at sites along parallel compass traverses, the distance between sites being measured by pacingl Sites may be described at a set number of paces (and therefore distance), or at points determined by the pedologist. The distance between traverses is determined by the complexity of the soil pattern (Cutler 1977, Dent and Young 1981).

GRID METHOD

Observations are regularly spaced to produce a rectangular grid over the area to be surveyed. Descriptions are then made at the intersecting points of the grid. This method is used in intensive surveys where the high density of observations require the precise plotting of sites. It can also be useful in areas where the soil pattern is very complex, to estimate the proportion of the different soil profile classes (Cutler 1977, Dent and Young 1981).

SITE AND SOIL PROFILE DESCRIPTION

Once the locations of soil profile description sites have been determined, and the position of the site recorded, both the site itself and the soil profile should be described.

The characteristics of the soil site record the specific soil forming factors (climate, relief, vegetation, parent material, and time) that have determined the genesis and properties of the soil body (Taylor and Pohlen 1962, Cutler 1977). The site characteristics which were recorded in this study include;

location
physiographic position
elevation
slope
parent rock
parent material
rainfall range
temperature range
soil temperature regime
soil drainage
flooding
erosion
past and present vegetation and land use.

Soil profile descriptions were recorded at sites where pits were excavated, cuttings spaded and at augured sites. As the dutch clay auger mixes the material somewhat as it is removed, and soil structure is often destroyed, descriptions are not as detailed at augured sites as they are at fully exposed profiles. Profiles were described to a depth of one metre or more, using the criteria and methodology outlined by Taylor and Pohlen (1962) in Soil

Survey Method. Features recorded at profile description sites include;

depths of horizons
colour
texture
consistence
structure
soil fauna and flora, i.e. worms and roots
stoniness
special features such as concretions and pans
horizon boundaries.

SOIL MAPPING UNITS

The smallest area that should be described in soil surveys is the pedon. This covers an area large enough to represent the nature and variability of the soils horizons and their properties. The area of a pedon can vary from 1-10 m^2 depending on the variability of the soil, but in general has a horizontal area or about $1m^2$ (Soil Survey Staff 1975).

Soil profile descriptions lead to the formation of conceptual groups called taxonomic units. These are individual kinds of soils that can be recognised as distinct entities and hence classified. Taxonomic units are defined by medial profiles which provide the central concept of the soil being described, and a stated allowable range of variability. A group of adjacent like pedons that have properties within the range of the conceptual properties of a soil series is known as a polypedon (Soil Survey Staff 1975, Dent and Young 1981, Palmer *et al* 1981).

On a soil map boundaries delineate areas of real soils which are as homogenous as possible. Each mapping unit represents either an area dominated by a single soil, or and area in which two or more soils occur. While real soil boundaries may be abrupt they are more commonly graduated over a distance of a number of metres. This leads to impurities within the mapping unit as gradual boundaries must be represented on the soil map by a line. Boundaries are inserted at the greatest rate of change of morphology. Thus soil mapping units contain an assemblage of like pedons (i.e. a polypedon) with, in places a smaller number of unlike pedons recognised as inclusions. A mapping unit is allowed up to 15% of its area to be occupied by inclusions (Taylor and Pohlen 1962, Soil Survey Staff 1975, Dent and Young 1981, Palmer *et al* 1981).

Ideally the basic unit of both mapping and classification is one containing a single kind of pedon, but ideal units are rarely large enough to be of general use when shown on soil maps (Taylor and Pohlen 1962). For this reason other more general mapping units are used.

Mapping units are divided into two main types; simple mapping units and compound mapping units. Each kind is further subdivided.

SIMPLE MAPPING UNITS

TYPE

Soil types consist of areas of near homogenous segments of soil (polypedons). They are found on uniform pieces of land over which the soil forming factors are nearly identical. They are given a geographical name to indicate the series to which they belong; followed by a textural name indicating the texture of the topsoil, and where necessary by added descriptive terms indicating colour, depth etc.

SERIES

Grouping of soil types alike in character and behaviour in the landscape. They should be developed in the same or similar parent material; have similar temperature and moisture regime; and have similar modal profiles, with horizons similar in vertical sequence, thickness and morphological properties, i.e. similar soil profile forms. Each series should have a unique combination of site features and morphological characteristics which can be assessed in the field.

PHASE

A subdivision of any category of the classification. Soils are subdivided according to any characteristic or combination of characteristics potentially significant to land use, for example depth, stoniness or drainage. May indicate transient or artificially induced changes not accompanied by significant change in the morphology of the soil body, i.e. flooding by irrigation.

VARIANT

Related to established series but differs in some essential characteristic. This unit is designed to avoid the unnecessary multiplication of series names. It is used to avoid establishing separate soil types for soils of minor extent without jeopardising the narrow definition of the soils (Taylor & Pohlen 1962, Cutler 1977, Dent & Young 1981).

COMPOUND MAPPING UNITS

ASSOCIATION

A group of geographically associated soils, each of which is confined to a particular facet of the landscape and which occur in a predictable pattern. Profiles are usually unlike and commonly consist of a toposequence or drainage sequence. Each soil unit is named and described, the association being named after one or more of its principle members. The soils which make up an association need not be related pedologically or lithologically, and may be used at various scales showing combinations of types, series, groups etc.

CATENA

The catena is a type of association where soils form a continuum in the landscape, such as that produced by a gradual change in morphology down a slope.

COMPLEX

Contain an intimate mixture of two or more soil types that cannot be differentiated on ordinary detailed soil maps because of the complexity of the soil pattern. They are given a local name or composite name from those of principle members. Units are described separately and if possible the soil pattern is also described, along with the percentage of each of the soil types present (Taylor & Pohlen 1962, Cutler 1977, Dent & Young 1981).

3.2.0 Literature review.

GENERAL SURVEY OF THE NORTH ISLAND.

(N.Z. Soil Bureau 1945).

The general survey of the soils of North Island was carried out by combined staff from Soil Bureau DSIR, and Extension Division Department of Agriculture. Its purpose was to obtain an overall picture of North Island soils, their productive potential and fertiliser requirements. The maps produced are not detailed, they have a scale of four miles to one inch (1:253 440), and the soil units contain sets of closely related soils or assemblages of soils rather than individual soil types. Survey work was carried out hurriedly during the war years, which led to uneven coverage. The soils were classified to group level and two of these groups, recent soils and secondary podzolic soils, were mapped within the study area.

RECENT SOILS FROM ALLUVIUM.

These are described as being typically found where inorganic material is periodically added to the land surface, and tend to lack differentiation into horizons. They include soils which are actively accumulating. Soil sets mapped within the study area include:

Manawatu loam, sandy loam, silt loam and clay loam (1).

Esk sand (1b).

Tukituki sandy loam, stony gravel, etc. (1c).

Kairanga silt loam and clay loam (2).

SECONDARY PODZOLIC SOILS.

These were described as forming in sediments relatively high in silica, including soils developed from aeolian sands. Only one soil set from this group was mapped in the study area.

Patea sand (23), (see appendix 2 to see the distribution of soils within the study area, appendix 3 for brief soil profile descriptions).

SOILS OF WAIRARAPA VALLEY.

(J.C.Heine 1975).

Information in the unpublished interim report was compiled by J.C.Heine from data by H.S.Gibbs and J.D.Cowie. The soil map is at a scale of one inch to two miles (1:126 720).

In the text of the report the Wairarapa Valley is divided into three physiographic regions: Western ranges, Central plains and Eastern hills; the study area being within the 'Central plain'. This physiographic region was further subdivided in order to describe the soil pattern which changes from west to east, mainly in response to climate, physiographic position and age; parent material remaining constant across the valley. All the soils are derived mainly from products of erosion of the greywacke ranges with a small contribution to the recent soils of silt and clay from erosion of the Tertiary sediments to the east.

The physiographic subdivision which includes the study area is that of the flood plains. Soils of the flood plains are found bordering the rivers and Lake Wairarapa where alluvium is accumulating. Soil profiles are weakly developed in these soils because of the short time they have been accumulating.

Several different soils are found within the study area (appendix 2). These include soils of the flood plains and swamps, sand dunes and river terraces.

SOILS OF THE FLOOD PLAINS AND SWAMPS.

Ruamahanga sand (1b).

Rapidly accumulating recent soil from alluvium.

Ahikouka silt loam (2).

Slowly accumulating gley recent soil from alluvium.

Pukeo clay loam (2a).

Rapidly accumulating gley recent soil from alluvium.

SOILS OF THE SAND DUNES.

Manihera sand (23).

Moderately leached central yellow-brown sand.

Kumenga mottled sand (23b).

Moderately leached gleyed yellow-brown sand.

SOILS OF THE RIVER TERRACES AND FANS.

Martinborough loam (12).

Moderately leached weakly gleyed central yellow-grey earth.

Brief soil profile descriptions of these soils can be found in appendix 3.

SOILS AND HORTICULTURE OF THE GREYTOWN DISTRICT.

(Cowie,J.D. and Money,S.P. 1965).

Although mapping the soils of a district approximately 60km northeast of the study area, the authors describe soil types also found in this survey as the soils around Greytown are also formed in alluvium eroded from greywacke in the Tararua Range. The map was produced at a scale of 1:24 400 to determine the extent and distribution of soils valuable for intensive use such as fruit and vegetable production.

Both Ruamahanga and Ahikouka soil series are described in this survey, (see appendix 3).

HOLOCENE MARINE SHORELINES.

(Heath,D.A. 1979).

Soil profiles were described from each of seven dune sets which were recognised. Soils descriptions in the appendices of this report are thorough, but it is not easy to determine which descriptions go with which dunes, as on the map the dunes are not numbered. From the text it is clear that dune one is the oldest and dune seven the youngest, but a number of the intermediate dune sets coalesce in places, making it difficult to determine which set is which.

Heath notes several trends in the changing of characteristics from the oldest to youngest dune sets including:

- A considerable thinning of the soil profile and concurrent decreasing horizon development;
- Progressive weakening of compaction in the subsoil;
- Colours in the B horizons becoming paler.
- Excepting dune seven, a decrease in organic carbon.

3.3.0 Description and distribution of soils.

One of the aims of this study was to produce a soil map of the study area at a scale of 1:25 000. The soil parent materials and the physiographic units on which the soils have formed have been described in the preceding chapter. Within this section the soil profile classes which were recognised and mapped will be described.

Each soil was defined and described using criteria which are easily identified in the field, such as colour, texture and structure. The following descriptions, based on soil morphology, along with the accompanying photographs should allow individual soil profile classes to be readily identified. Scale in the photographs is indicated by a graduated tape or a spade (see figure 22).

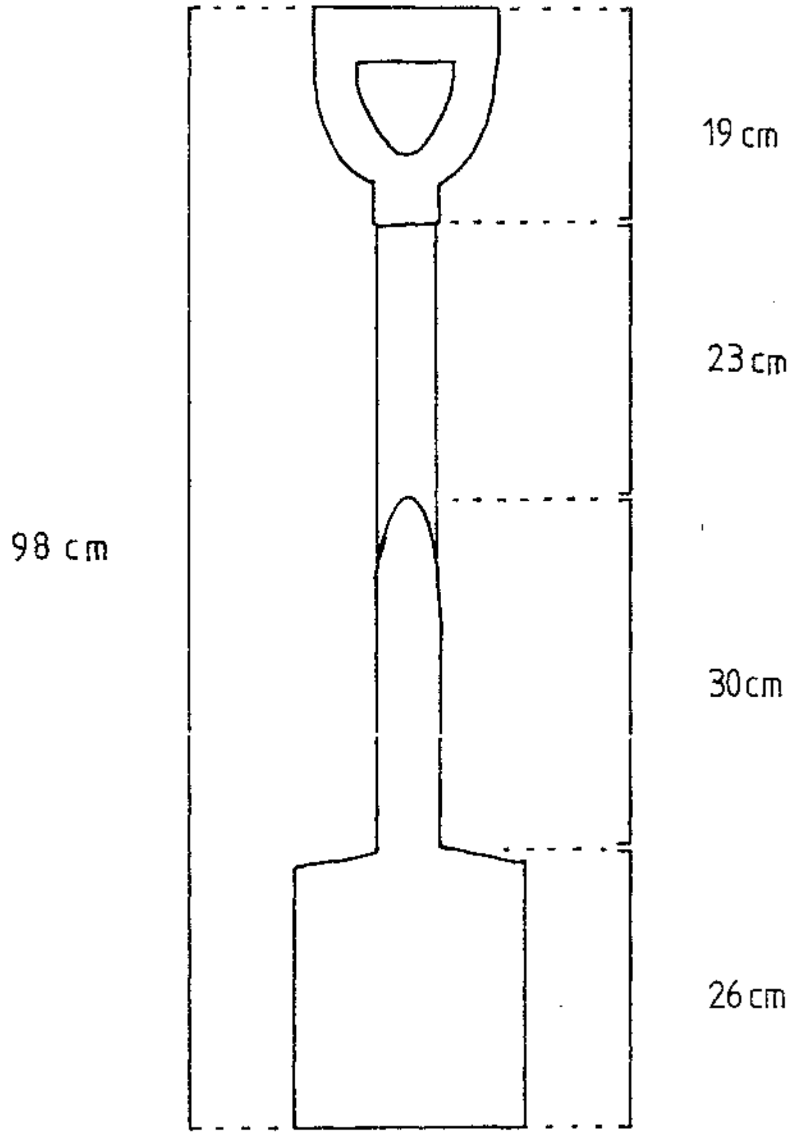


Figure 22 Spade dimensions

To assist with assessing the depths of soil horizons and profiles in the following photographs.

PEDOLOGICAL LEGEND

(to accompany the map in the back pocket)

Moderately leached central yellow-brown sands

- Kahutara sand
- Wairio sand
- Wairio mottled sand
- Manihera sand
- Manihera mottled sand
- Parera sand

Moderately leached gleyed central yellow-brown sands

- Mangatete sand
- Manihera mottled sand on silty clay
- Kumenga mottled sand - dune phase
- Kumenga mottled sand - dune phase

Slowly accumulating gleyed recent soils from alluvium

- Ahikouka silty clay loam
- Ahikouka stony silty clay loam
- Te Pare stony silty clay loam
- Ahikouka silty clay loam on sand

Rapidly accumulating gley recent soils from alluvium

- Pukeo clay loam
- Pukeo clay loam on sand
- Lake shore sand

Rapidly accumulating saline gley soils

- Onoke silty clay
- Te Hopai clay
- Te Hopai sandy clay

PHYSIOGRAPHIC LEGEND
(to accompany the map in the back pocket)

Soils of the sand dunes

Ka	Kahutara sand
Wo-Mt	Wairio - Mangatete association
Mn-Kg1	Manihera - Kumenga association
Kg1-Kg2	Kumenga mottled sand association
Mn3	Manihera mottled sand on silty clay
Pa	Parera sand

Soils of the slowly accumulating floodplain

Ak1	Ahikouka silty clay loam
Ak3	Ahikouka silty clay loam on sand
Ak2+Tp3	Ahikouka stony silty clay loam and Te Pare stony silty clay complex

Soils of the rapidly accumulation floodplain

Pu1	Pukeo clay loam
Pu2	Pukeo clay loam on sand
On	Onoke silty clay
S	Lake shore sand

Soils of the old lagoon beds and swamps

Th1	Te Hopai clay
Th2	Te Hopai sandy clay

The pedologic and physiographic legends to accompany the soil map in the back pocket are found in this section (tables 2 & 3).

For more detailed information about the site or soils, appendix four - soil taxonomic unit descriptions should be consulted. Appendix five - soil mapping unit descriptions, is located in the back pocket (along with the maps), and provides ready access to information when interpreting the soil map.

3.3.1 Soils of the sand dunes.

DUNE SET ONE

KAHUTARA SAND.

Kahutara sand is a moderately leached yellow-brown sand identified for the first time in this survey. The soils typically have a brownish black friable A horizon with moderately developed medium nut and block structure breaking to fine nuts and crumbs; over a dull yellowish brown B horizon with weak to moderately developed coarse nut and block structure; over a yellowish brown unstructured BC horizon; overlying loose sand. Parent material is the excessively drained yellow-brown aeolian sand which forms dune set one (see physiographic units map). The dunes extend north-east to south-west along the eastern side of Lake Wairarapa, a small area of Kahutara sand soils being found in the north-eastern part of the study area (see soils map) (plate 6). Kahutara sand (plate 7) is found on the crests and sides of dune set one where drainage is rapid. No mottled soils were described from this dune set.

Soils on dune set one were mapped as Patea sand in the General Survey of the North Island (Soil Bureau, 1954). However the typical soils of this set are found along the Wanganui coastline developed in sand which contains an appreciable amount of ferro-magnesian minerals. These are supplied by both the Taranaki Volcanic Zone, and the Central Volcanic Zone. The quartzo

Plate 6 Dune set one.

Kahutara sand is found on the crests and sides of dune set one, developed in excessively drained aeolian sand. The dunes sit on a low cliff (part of the highest Holocene shoreline), and reach elevations of up to 40 metres.

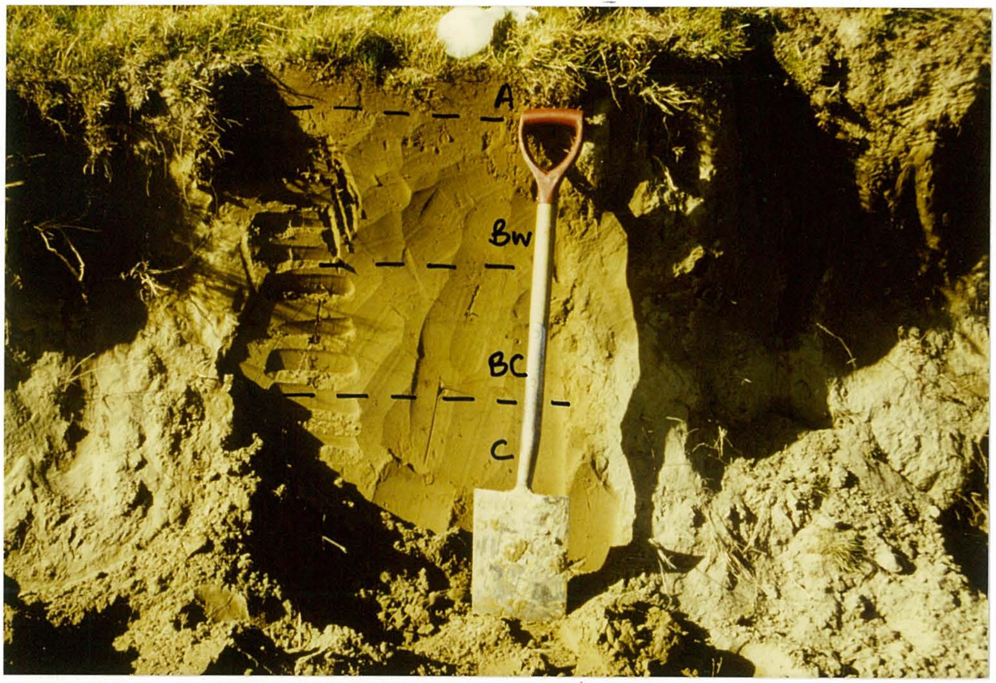


Plate 7 Kahutara sand

Kahutara sand soils are distinguished from other dune soils by their A/Bw/BC/C profiles. These soils characteristically have dark, friable, sandy clay loam topsoils with moderately developed medium nut and block structure; a dull yellowish-brown Bw horizon with weakly developed coarse nut and block structure; over yellowish brown BC and C horizons with single grain structure.

Plate 8 Dune set two

The dunes of dune set two have been blown across part of the slowly accumulating floodplain in which the soils of the Ahikouka series have formed. The excessive drained Wairio sand (Wo1) is found on the dune crests and shoulders, Wairio mottled sand (Wo2) on the lower slopes and the imperfectly to poorly drained Mangatete sand (Mt) on any gentle toeslopes and in swales.

-feldspathic sand dunes around Lake Wairarapa have a very different mineral assemblage in the parent sand and so it is not appropriate for them to be mapped as Patea sand. In Heine (1975) the soils of dune set one were mapped as Maniher sand (see appendix 2). However these soils are described as having profiles with only A and C horizons, lacking any B horizon development (Appendix 3). For this reason it was considered appropriate to create a new name for this soil, keeping the title Manihera sand specific for unmottled AC profiles developed in sand. Kahutara sand correlates to Heath's (1979) soil on dune system one.

Kahutara sand is a soil of moderate value for food production. The main limitation to production is that of dryness. The excessively draining sand retains very little moisture, and so during summer months the soil rapidly dries out, lack of moisture stressing vegetation and slowing growth. The steep sides of dune set one are unsuitable for cropping or horticulture. Apart from slope, any disturbance of the soil resulting in the exposure of loose sand to strong winds could lead to severe wind erosion. Kahutara sand is best kept under pasture and used for grazing during wet winter months when it will be well drained and have good pasture growth. These soils are currently being used as pasture for sheep and cattle.

DUNE SET TWO

WAIRIO SAND.

Wairio sand is a moderately leached yellow-brown sand identified for the first time in this survey. Profiles have a brownish black friable A horizon with weak to moderately developed nut and block structure; over an unmottled dull yellowish brown B horizon with very weakly developed coarse nut and block structure; over loose sand. Wairio sand soils are distinguished from Kahutara sand soils by their less well developed structure, thinner B horizons and the lack of a transitional BC horizon.

Wairio sand is found on the crests and shoulders of dune set two (plate 8) which extend north-east to south-west along the eastern side of Lake Wairarapa. Within the study area dune set two extends between the north-eastern boundary of Mangatete Stream, to a few hundred metres south of Oporua floodway. Wairio sand soils (plate 9) are formed in the excessively drained yellow brown aeolian sand of dune set two. They grade into Wairio mottled sand soils which are found on the well drained to moderately well drained backslopes of the dunes.

Wairio sand soils were previously mapped as Patea sand (Soil Bureau, 1954), and Manihera sand (Heine, 1975). As Patea sand soils are typically formed in sands containing appreciable amounts of ferromagnesian minerals, the quartzo-feldapthic dunes around Lake Wairarapa do not really belong in this set. Manihera sand as described by Heine (1975) encompasses well drained sandy soils with an AC profile (see appendix 3), whereas Wairio sand soils also have B horizons. Wairio soil is not shown as a simple mapping unit on the soil map, but is a member of the Wairio-Mangatete association (Wo-Mt). Figure 23 shows the relationship between the soils included in the association.

Wairio sand is of moderate value for food production (see appendix 4 or 5). The main limitation to its intensive use is dryness. Soils are formed on the crests and shoulders of the dunes, slopes ranging from 5-23°, but gently sloping areas are of minor extent and slope can also be a limiting factor, preventing cropping and horticulture. Soils become excessively dry during the summer limiting vegetation growth. To prevent wind erosion Wairio sand is best kept under continuous cover, such as is provided by pasture or forest. These freely draining soils provide good winter pastures and their present use is to provide pasture for sheep and beef cattle.

WAIRIO MOTTLED SAND.

Wairio mottled sand is a moderately leached weakly gleyed yellow-brown sand described for the first time in this survey. It has a brownish black

Plate 9 Wairio Sand

Wairio sand soils have a dark, friable, sandy loam topsoil with weak to moderate nut and block structure, and a dark brown sandy B horizon with weakly developed coarse nut and block structure overlying dull yellowish-brown loose sand. Sites which have developed under bracken have deep dark topsoils, such as that in the photo above.

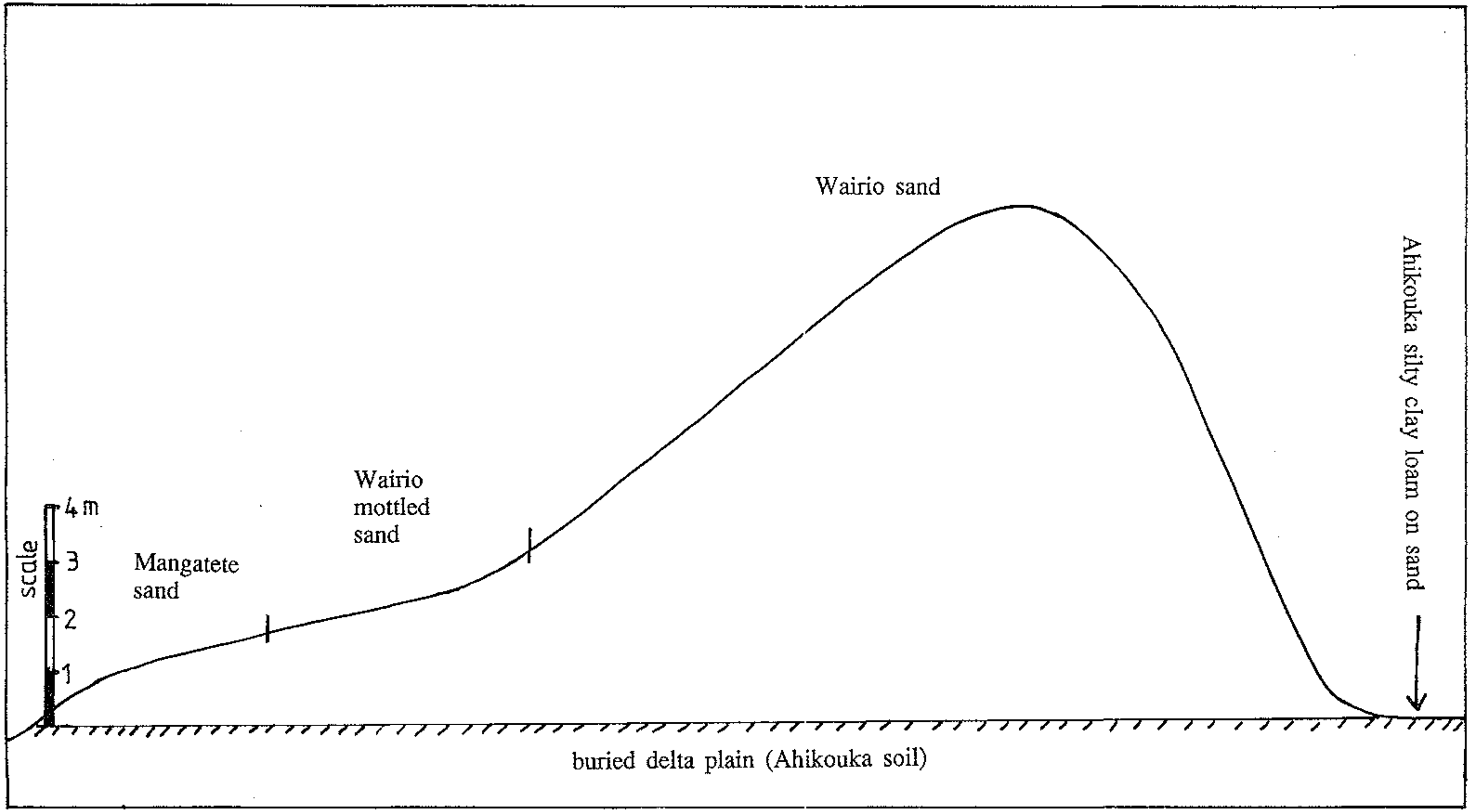


Figure 23 Cross section through dune set two showing the relationship of soils to physiographic position.

friable topsoil over a dull yellowish brown B horizon with weakly developed coarse block structure; overlying mottled subsoils. Ochreous mottles are found at depths greater than 45cm and low chroma mottles may occur at greater depths, i.e. greater than 60cm.

Wairio mottled sand (plate 10) is developed in moderately well drained sites in the aeolian sand of dune set two (see physiographic units map) (plate 8). These are generally on the backslopes and the higher parts of some toeslopes.

Wairio mottled sand has been previously mapped as Patea sand (New Zealand Soil Bureau 1954) and Manihera sand (Heine 1975). Patea sand soils develop in sands with a much higher ferromagnesian mineral content than the sands around Lake Wairarapa. Thus the soils of the quartzo-feldspathic sands along the eastern shore of Lake Wairarapa should be in a separate soil set to those of the Wanaganui coastline. Heine (1975) mapped dune set two as Manihera sand (see appendix 2). The description of Manihera sand however is of an unmottled soil with an AC profile, whereas Wairio mottled sand soils have a weakly developed B horizon overlying mottled subsoils. Wairio mottled sand is a new name introduced in this survey to distinguish this soil both from those soils with AC profiles, and the similar but unmottled Wairio sand.

Wairio mottled sand is found together with Wairio sand and Mangatete sand on dune set two. The physiographic position of Wairio mottled sand is shown on figure 23 along with its relationship to the other soils. The three soils are not mapped separately but as the Wo-Mt association (see appendix 5 and the soil map).

These soils are of moderate value for food production. Dryness, followed by slope are the main limiting factors (see appendix 4). Soils are not suited for cropping or horticulture due to summer moisture deficiency, slope, and lack of strongly developed soil structure. They are however well suited to

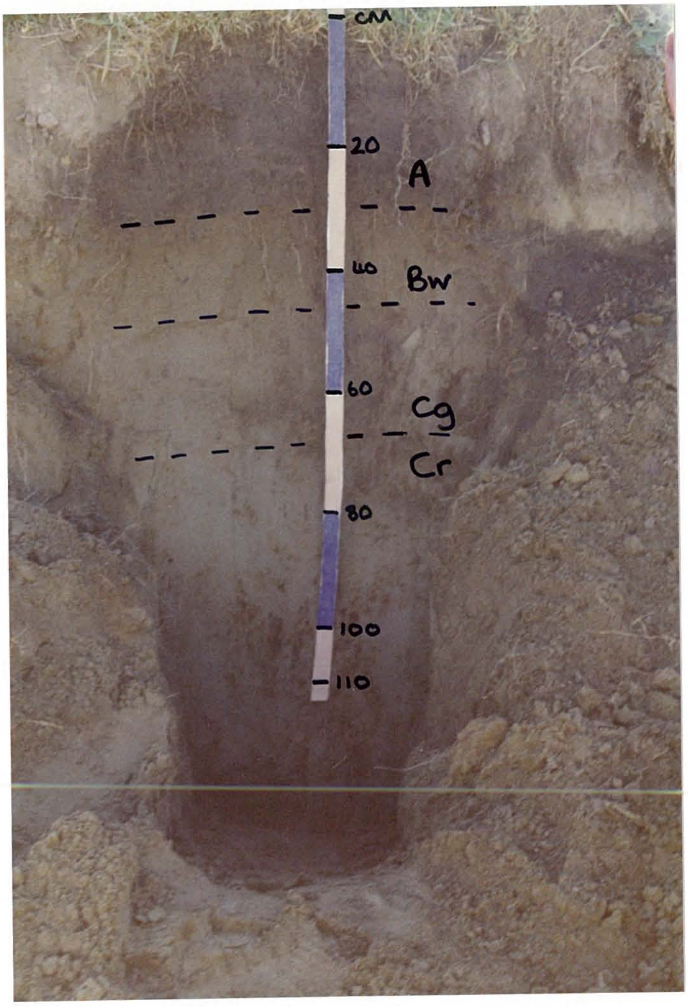


Plate 10 Wairio mottled sand

Wairio mottled sand soils are distinguished from other dune soils by their A/Bw/Cg profiles. Soils characteristically have deep dark friable sandy clay loam topsoils, with weak-moderately developed not structure; a dull yellowish-brown Bw horizon with weakly developed coarse block structure; over mottled C horizons with single grain structure. Both ochreous and low chroma mottles are present in the C horizons, the proportion of low chroma colours increasing with depth.

pasture and forestry which also keep soils protected against the threat of wind erosion. Although drying out somewhat in summer, these soils make excellent winter and spring pastures. They are currently used to provide pasture for sheep and beef cattle.

MANGATETE SAND.

Mangatete sand is a moderately leached gleyed yellow-brown sand first described in this survey. Brownish black friable topsoils (which may contain ochreous mottles) with moderately developed coarse nut and block structure; overlie yellowish brown and reddish brown mottled B horizons with weakly developed coarse block structure; overlying grey and reddish brown mottled unstructured subsoils.

Parent material is the aeolian sand of dune set two (see physiographic units map) (plate 8), Mangatete sand being found on the imperfectly to poorly drained toeslopes of the dunes and in the swales between them. Mangatete sand soils (plate 11) grade into the better drained Wairio mottled sand soils.

Mangatete sand was previously mapped by New Zealand Soil Bureau (1945) and Heine (1975) as Patea sand and Manihera sand respectively. As Patea sand soils are typically formed in sands containing appreciable amounts of ferromagnesian minerals, the quartzo-feldapthic dunes around Lake Wairarapa do not really belong in this set. Manihera sand as described by Heine (1975) encompasses well drained sandy soils with an AC profile (see appendix 3), not applicable to the poorly drained Mangatete sand soils which also have B horizons. In this survey a new name was assigned to this soil, to enable it to be distinguished from the previously mapped AC soils, and the similar but better drained Wairio mottled sand.

Mangatete sand grades into the better drained Wairio mottled sand and is mapped as part of the Wairio-Mangatete (Wo-Mt) association (see the soil

Plate 11 Mangatete sand

Mangatete sand soils have A/Bg/Cr profiles. They have a deep dark friable topsoil (which may have fine ochreous mottles), with moderately developed coarse nut and block structure; a yellow-brown and dark-reddish-brown mottled Bg horizon, with weakly developed coarse block structure; over an olive-grey and reddish-brown mottled Cr horizon with a single grain structure. In late spring the water table was found at a depth of approximately 120m.

map). The relationship between the soils and the physiographic unit upon which they have formed is shown by Figure 23.

These soils are of high potential value for food production (see appendices 4 and 5). They may be limited by drainage in winter, but they are porous rapidly draining soils and although in winter the water table may be high, ponding of surface water rarely occurs except where toeslopes fringe lagoons. Whilst they are not suited to horticulture because of the weak soil structure, the gentle slopes (generally less than 5°), and availability of moisture through spring and early summer make these soils suited to pasture, tree production and cropping, especially fodder crops. They are presently used as grazing for sheep and cattle.

DUNE SET THREE

MANIHERA SAND.

Manihera sand is a moderately leached central yellow-brown sand. These soils have a dark brown friable A horizon with weakly developed medium nut and block structure; overlying yellow brown loose sand. Transitional AC horizons are common. They are distinguished from Kahutara sand soils and Wairio sand soils by their much thinner A horizons, and the lack of a structured Bw horizon.

Manihera sand soils are developed in the aeolian sand of dune set three (plate 12). These dunes extend north-east to south-west along the lake margin. The main areas of dune set three within the study area are found between Oporua floodway and the former channel of the Ruamahanga River (see the physiographic map). Manihera sand (plate 13) is developed in the excessively drained crests and shoulders of the dunes.

Manihera sand was mapped as Patea sand by New Zealand Soil Bureau (1954) and as Manihera sand and Kumenga mottled by Heine (1975) (Appendix 2). These soils should not be included in the Patea sand set. Unlike Patea sand which is developed in ferromagnesian rich sands,

Plate 12 Dune set three

The parabolic transgressive dunes of dune set three have moved over the Pukeo clay loam and Pukeo clay loam soils behind them. The dunes are the parent material for the excessively drained Manihera sand (X), the well drained Manihera mottled sand (Q) and the imperfectly drained Kumenga sand-dune phase (Kg1). Kumenga sand-swale phase (Kg2) is found in the low areas between dunes.

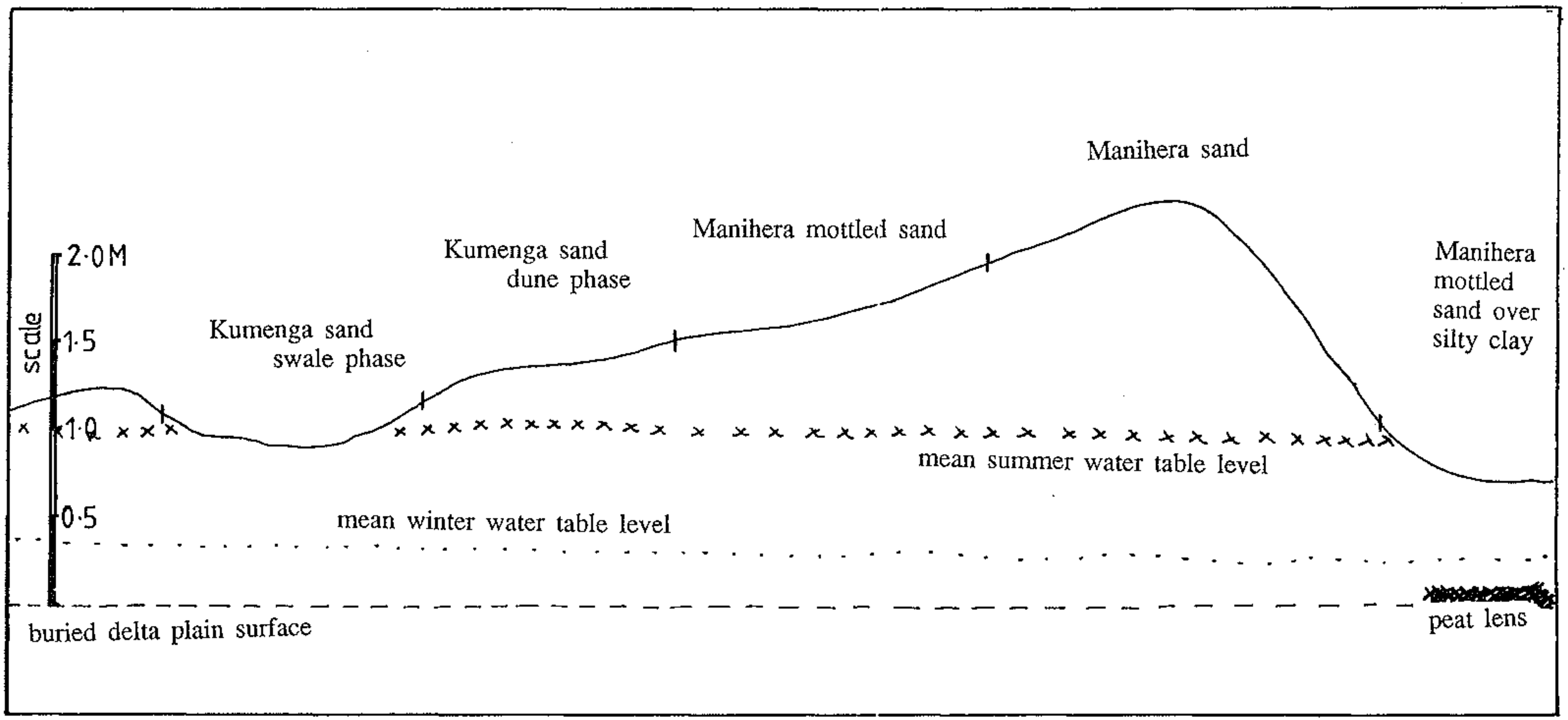


Figure 24 Cross section through dune set three showing the relationship of soils to physiographic position.

Manihera sand soils are formed in quartofeldspathic sand. The name Manihera sand was used by Heine (1975) to describe well drained sand soils with AC profiles. The name was retained for these soils as they fit the soil profile description given by Heine (see appendix 3) very closely.

Manihera sand is mapped as part of the Manihera-Kumenga association (Mn-Kg1), along with other soils found on dune set three. Its position on the dunes and relationship to the other soils can be seen on figure 24.

These soils are of moderate value for food production being limited by dryness and slope (up to 30°). The free draining nature of the sandy soils, whist of value in winter, leads to moisture deficiencies and even the development of water repellency in summer. Steep slopes and lack of structure make these soils unsuitable for cropping or horticulture and vulnerable to wind erosion (plate 14). To prevent wind erosion soils should be kept under the protection of permanent vegetation cover. These soils provide well drained pastures during wet months and are currently in improved pasture being grazed by sheep and beef cattle.

MANIHERA MOTTLED SAND.

Manihera mottled sand is a moderately leached, weakly gleyed yellow-brown sand described for the first time in this survey. Brownish black A friable horizons with moderately developed medium to coarse block structure overlie a dull yellowish brown unstructured subsoil which has grey and bright brown mottles at depths greater than 45cm. Horizons transitional between the A and C horizons may be present, but the presence of concretions is rare. These soils are not as well developed as Wairio mottled sand soils, lacking their structured B horizon.

Manihera mottled sand soils (plate 15) are found on the moderately well drained backslopes and toeslopes of dune set three. The parent material is quartzofeldspathic aeolian sand. Manihera mottled sand grades into

Plate 13 Manihera sand

Manihera sand soils are developed in the excessively drained aeolian sand of dune set three. Soils have a dark brown, friable, sandy loam topsoil with weakly developed medium nut and block structure; over olive-brown to yellowish brown loose sand with single grain structure. Transitional AC horizons are common. Where wind erosion has led to the formation of blowouts, well developed soil profiles are buried by almost featureless sand as in the photo above.

Plate 14 An active blowout on dune set three

Blowouts form when the vegetation cover of sand dunes is disturbed, exposing a face of loose sand to the wind. The sand is remobilised by strong winds, being blown into drifts which cover the former surface, thus producing buried soils. As sand is much more easily moved by the wind when it is dry, blowouts tend to occur on dune crests and shoulders where soils are dry throughout much of the year.

Manihera sand as drainage improves, and Kumenga mottled sand-dune phase where drainage is poor (figure 24).

Manihera mottled sand was mapped as Patea sand by New Zealand Soil Bureau (1954), and as Manihera sand and Kumenga mottled sand by Heine (1975) (see appendix 2). Patea sand soils develop in sands with a much higher ferromagnesian mineral content than the sands around Lake Wairarapa. Thus the soils of the quartzofeldspathic sands along the eastern shore of Lake Wairarapa should be in a separate soil set to those of the Wanaganui coastline. Manihera sand and Kumenga sand soil profiles describe a well drained and a poorly drained sandy soil with AC profiles respectively. As Manihera mottled sand soils were considered to have characteristics part way between those of the unmottled Manihera sand and the gleyed Kumenga mottled sand they were given the new title.

This soil is mapped as part of the association Manihera - Kumenga (Mn-Kg1) along with Manihera sand and Kumenga sand - dune phase. Figure 24 shows the relationship between them and the physiographic unit in which they have developed.

Manihera mottled sand is of moderate value for food production the main limitations are dryness and slope. Summer dryness slows pasture and tree growth in summer. Slope and the lack of subsoil structure make the soil unsuited to cropping or horticulture. They make good winter and spring pastures, being dry while other soils pond water. They are presently in improved pasture, being grazed by sheep and beef cattle.

KUMENGA SAND - DUNE PHASE.

Kumenga sand - dune phase is a weakly leached gleyed yellow-brown sand. Soils have a dark brown friable A horizon with moderately developed medium nut structure, over a grey and yellowish brown mottled unstructured subsoil. These soils are distinguished from Mangatete sand soils by their lack of a structured B horizon.

Plate 15 Manihera mottled sand

Manihera mottled sand soils are developed in the moderately well drained aeolian sand of dune set three, and have an A/C profile with mottles at depths greater than 45cm. They have a dark, friable, sandy clay loam A horizon with moderately developed medium to coarse block structure; a firm yellowish-brown subsoil with single grain structure; over a grey and bright brown sand to sandy loam with single grain structure. The proportion of low chroma mottling increases with depth.

These soils are developed in the aeolian sand of dune set three (physiographic units map), and are found on poorly drained toeslopes and around hummocky dunes less than one metre high. They grade into Manihera mottled sand where drainage improves and into Kumenga sand - swale phase in local depressions where drainage is very poor (plate 16), (figure 24).

Kumenga sand - dune phase was mapped previously as Patea sand (New Zealand Soil Bureau, 1954), and as Manihera sand and Kumenga mottled sand (Heine, 1975) (see appendix 2). These soils should not be included in the Patea sand set. Unlike Patea sand which is developed in ferromagnesian rich sands, Kumenga sand - dune phase soils (plate 17) form in quartofeldspathic sand. The soils are very similar to Kumenga mottled sand described by Heine (appendix 3) and the name was therefore retained for this soil. However two phases of Kumenga mottled sand were recognised in this survey; a dune phase and a swale phase. The term 'mottled' was dropped so that naming would be consistent with that of dune set two.

Kumenga sand - dune phase is mapped along with the other soils of dune set three as part of the Mangatete - Kumenga association, and is also included as a member of a complex in conjunction with Kumenga sand - swale phase. Showing the individual distribution of the two Kumenga sand soils is not practicable at the scale of 1:25 000, and the exclusion of Kumenga sand - dune phase from the association of soils found on dune set three would have ignored an important soil pattern. In this way more of the large area covered by the two Kumenga soils is separated from the more easily delineated soils of dune set three.

Kumenga sand - dune phase is of low to moderate value for food production, the dominant limitation being poor drainage. The soils are not recommended for forestry or horticulture due to the poor drainage and also lack of subsoil structure for the latter. They are, however, reasonable soils for cropping and pasture production. Pasture on Kumenga sand - dune

Plate 16 The Kumenga sand association

Kumenga sand, dune phase and swale phase are found together in the landscape and would be difficult to map separately at a scale of 1:25 000. Kumenga sand-swale phase (Kg2) is typically found in low lying very poorly drained sites such as that in the foreground of the photo. Kumenga sand-dune phase (Kg1) is found on the poorly drained low lying dunes (less than one metres in height). Examples can be seen in the mid-ground of the above photo.

Plate 17 Kumenga sand-dune phase

Kumenga sand-dune phase is developed in the poorly drained aeolian sand of dune set three. Soils typically have a dark brown, friable, silty clay loam A horizon with moderately developed medium nut structure; over grey and yellowish brown mottled sandy subsoil with single grain structure. Profile may over lie silt or clay rich layers at depths of approximately one metre (see photo). These are deltaic sediments over which the dunes have formed.

phase will remain green when that of more well drained sites starts to become stressed due to lack of moisture. Currently in pasture used for sheep and cattle.

KUMENGA SAND - SWALE PHASE.

This soil is a weakly leached gleyed yellow-brown sand. Dark brown friable frequently mottled A horizons with moderately developed medium nut and block structures; overlie grey and brown mottled unstructured sand. Concretions may be found within the profile. Occasionally the sandy parent material may overlie silty sediments at depth, i.e greater than 90cm.

Kumenga sand - swale phase (plate 18) is developed in aeolian sand associated with dune set three (see physiographic units map), and is found in poorly drained swales between the dunes and in low lying areas between dune sets three and four. The dunes have advanced over silt and clay rich swampy deposits and sometimes these are exposed in the bottom part of the profile, the sand veneer being less than one metre thick. These soils grade into Kumenga sand - dune phase on slightly higher sites, and into Kumenga sand on silty clay where silty sediments are found at less than 90cm.

Kumenga sand - swale phase was mapped previously as Patea sand by New Zealand Soil Bureau (1954), and Kumenga mottled sand by Heine (1975) (see Appendix 2). These soils should not be included in the Patea sand set. Unlike Patea sand which is developed in ferromagnesian rich sands, Kumenga sand - swale phase soils form in quartofeldspathic sand. The name Kumenga sand was retained as profiles described in this survey match those described in the extended legend of Heine (appendix 3), but the term 'mottled' was left out to be consistent with the naming of soils on dune set two.

Kumenga sand - swale phase is mapped as part of a complex along with Kumenga sand - dune phase.

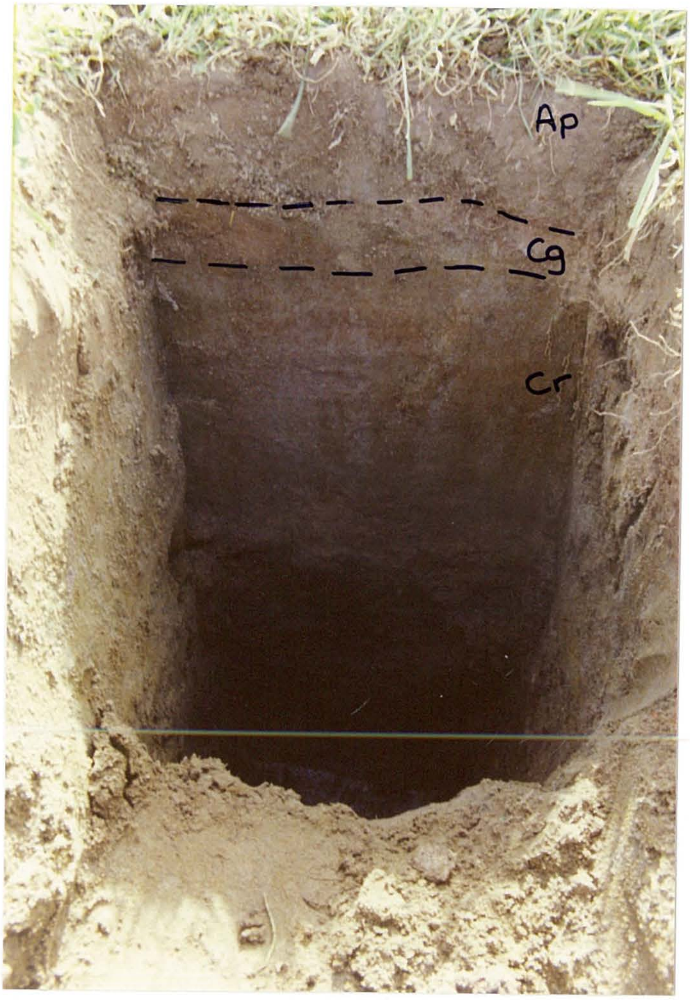


Plate 18 Kumenga sand-swale phase

Kumenga sand-swale phase is developed in the very poorly drained aeolian sand associated with dune set three. Soils have a dull yellowish brown to dark brown, friable, sandy clay loam A horizon with moderately developed medium nut and block structure. The A horizon may be mottled and overlies grey and brown mottled sandy subsoils with single grain structure. Profiles may be layered with silts and clays at depth or overlie silt and clay rich horizons.

Soils are of low to moderate value for food production, all uses being limited by the very poor drainage. Although water may be ponded during winter, the availability of moisture can be important for pasture growth in spring and early summer as other soils start to dry out. Currently, uses include semi-improved and rough grazing for sheep and cattle.

DUNE SET FOUR

PARERA SAND.

Parera sand is identified for the first time in this survey. Soils have a thin brownish black friable to loose topsoil with very weak fluffy structure, overlying greyish olive loose sand.

Parera sand is developed in the somewhat excessively drained aeolian sand of dune set four (plate 19). These dunes cover a small area on the eastern lake margin near the mouth of the former Ruamahanga River channel (physiographic units map). Parera sand soils (plate 20) are distinguished from all the other dune soils by their very thin topsoils with very weakly developed soil structure, which overlie loose sand. No transitional horizons are found.

Parera sand soils were previously mapped as Esk sand (New Zealand Soil Bureau, 1954), and Ruamahanga sand (Heine, 1975) (see appendix 2). It was thought desirable to distinguish this aeolian dune sand from sand deposited by water, the name Parera sand being introduced for this purpose. These soils are mapped as a simple mapping unit.

Soils are of low value for food production, limited by dryness (see appendix 4). The lack of moisture coupled with the lack the lack of strongly developed structure even in the topsoil makes Parera sand soils very susceptible to wind erosion if exposed to strong wind, they are better suited to pasture than cropping, horticulture or forestry. They are currently vegetated by thick gorse and lupin, interspersed with small patches of a variety of weeds and grasses.

Plate 19 Parera sand

Parera sand soils are developed in the aeolian sand of dune set four. These dunes bordering on the lake margin are the most recent in the study area, and are generally less than three metres in height.

KUMENGA SAND ON SILTY CLAY.

Kumenga sand on silty clay is a moderately leached gleyed central yellow-brown sand recognised for the first time in this survey. Soils have dull yellowish brown weakly structured A horizons, over grey and brown mottled sandy subsoils, overlying grey and yellowish brown silty clay sediments. Peat and vegetation in various stages of decomposition may be found at the contact between the underlying silty sediments and the overlying sand.

These soils are developed in the aeolian sand which forms dune set three. Present day soil formation does not extend down as far as the buried surface.

As the area of Kumenga sand on silty clay is very small the limitations and potentials of this soils were not assessed.

Kumenga sand on silty clay was mapped as Patea sand by New Zealand Soil Bureau (1954), and Kumenga mottled sand by Heine (1975) (see appendix 2). This soil differs from Kumenga mottled sand in that while it is developed in sand , the profile includes much silty material, and it was considered to be different at type level.

Kumenga sand on silty clay loam is mapped as a simple mapping unit. It was not included within the association of soils developed on dune set three (Mn-Kg1) as it has such a limited, scattered and relatively unpredictable occurrence.

3.3.2 Soils of the slowly accumulating flood plain.

AHIKOUKA SILTY CLAY LOAM.

Ahikouka silty clay loam is a slowly accumulating gleyed recent soil. It has a dull yellowish brown friable A horizon with well developed medium nut and crumb structure; over a yellow orange, grey and dark brown mottled B horizon with moderately to well developed coarse nut and block structure;

Plate 20 Parera Sand

Soil profiles typically have a thin brownish-black topsoil with very weak crumb structure, overlying greyish-olive loose sand.

overlying a yellowish brown and grey mottled unstructured subsoil. Transitional AB horizons may be present, as may concretions.

Ahikouka silty clay loam is developed in imperfectly to poorly drained alluvium and is found on the slowly accumulating flood plains of the Ruamahanga River (plate 21). In this study Ahikouka silty clay loam soils (plate 22) were found at the northern end of the slowly accumulating floodplain, in the vicinity of Whareroto road (see the soil map).

Ahikouka silty clay loam was mapped as Manawatu silt loam etc. by New Zealand Soil Bureau (1954), and as Pukeo clay loam by Heine (1975) (see appendix 2). In Soil Bureau Record 40 (Heine 1975), Ahikouka silty clay loam is described as a slowly accumulating silt loam textured soil developed in silty alluvium, and Pukeo clay loam as a rapidly accumulating clay loam textured soil developed in silt and clay sediments (see appendix 3 for brief soil profile descriptions). It would be expected that a slowly accumulating soil would have more strongly developed horizonation than a rapidly accumulating soil, and also more well developed soil structure. Using the criteria of soil morphology including colour, texture and structure, it seems that Pukeo clay loam and Ahikouka silty clay loam have apparently been transposed on the map accompanying Soil Bureau Record 40. In this survey, the position of these soils were reversed. Therefor the name 'Ahikouka' has been retained, although silty clay loam was substituted for silt loam, to reflect the textures of the profiles described in this survey.

Ahikouka silt loam has been mapped in a simple mapping unit (see appendix 5 and the soil map).

These soils are of high potential value for food production. They require artificial drainage to lower the water table and prevent ponding in winter months. With good drainage they are suited to most purposes, being valued for fruit and vegetable production in the Greytown area.

Plate 21 The slowly accumulating floodplain.

The plain shown in the photo above is the physiographic unit on which the Ahikouka series soils and Te Pare stony silty clay loam soils are formed. The plain is a former delta of the Ruamahanga River and is now only occasionally flooded. In the photo above, the leeward face of dune set two can be seen.

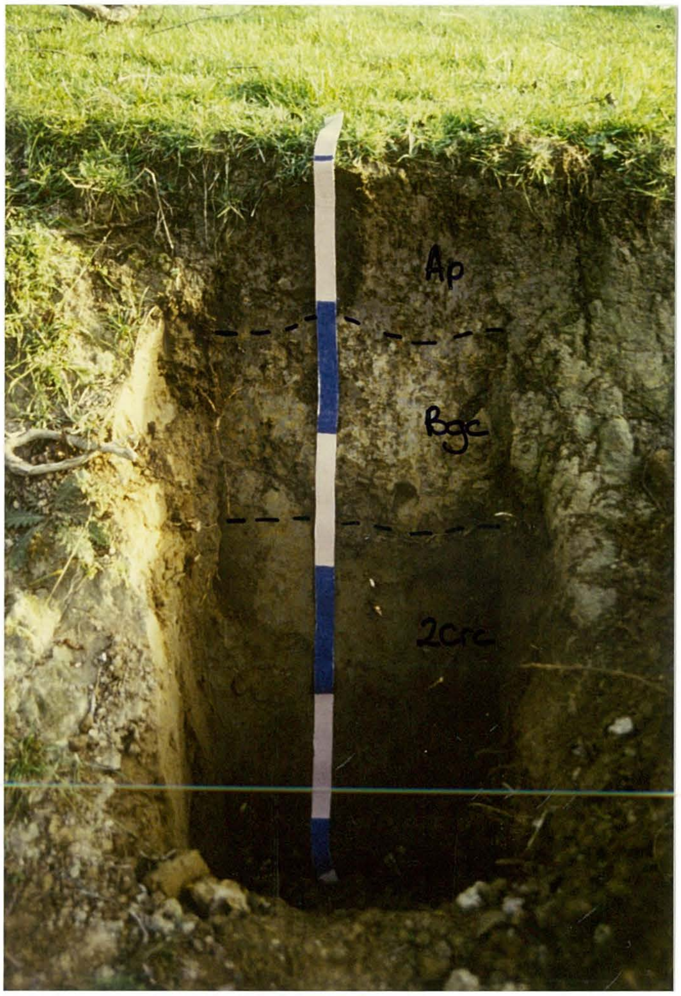


Plate 22 Ahikouka Silty clay loam

Ahikouka silty clay loam soils characteristically have a dull yellowish-brown, friable A horizon with well developed medium nut and crumb structure, over a firm mottled B horizon (including low chroma mottles, which contains concretions and has coarse nut and block structure, over yellowish-brown and grey mottled sandy clay loam subsoils.

AHIKOUKA SILTY CLAY LOAM ON SAND.

Ahikouka silty clay loam on sand is a slowly accumulating gleyed recent soil identified for the first time in this survey. Brownish black friable A horizons with moderately developed medium to fine nut and crumb structure overlies; dull yellowish brown and bright brown mottled B horizons (containing concretions) with moderately developed medium nut and block structure over; grey and yellowish brown mottled unstructured sands with occasional clay lenses. It is distinguished from Ahikouka silty clay loam by the texture of the subsoils.

Ahikouka silty clay loam on sand (plate 23) is developed in imperfectly to poorly drained alluvial silts and sands, and is found over a large area at the southern end of the slowly accumulating flood plains of the Ruamahanga River.

Ahikouka silt loam has been mapped previously as Manawatu loam etc. (New Zealand Soil Bureau 1954), and Pukeo clay loam (Heine 1975); (see appendix 2). The positions of Pukeo clay loam and Ahikouka clay loam were apparently reversed on the map accompanying Soil Bureau Record 40 (Heine, 1975), as the description of Ahikouka silt loam matches that of the soils found in this survey (Appendices 2,3 & 4). The main difference between the profile described in the extended legend of Soil Bureau Record 40 (Heine, 1975) and those found in this survey is that topsoils were found to have silty clay texture, not silt loam, and that profiles overlie coarse sandy sediments by 40-60cm. The name 'Ahikouka' was retained and the term 'silty clay loam on sand' added to more fully describe the soil.

Ahikouka silty clay loam on sand has been mapped alone as a simple mapping unit (soil map).

It is a soil of high potential value for food production, capable of being used for intensive purposes when well drained. In the Greytown area these soils are used for orchards and market gardens (Cowie and Money, 1965). The

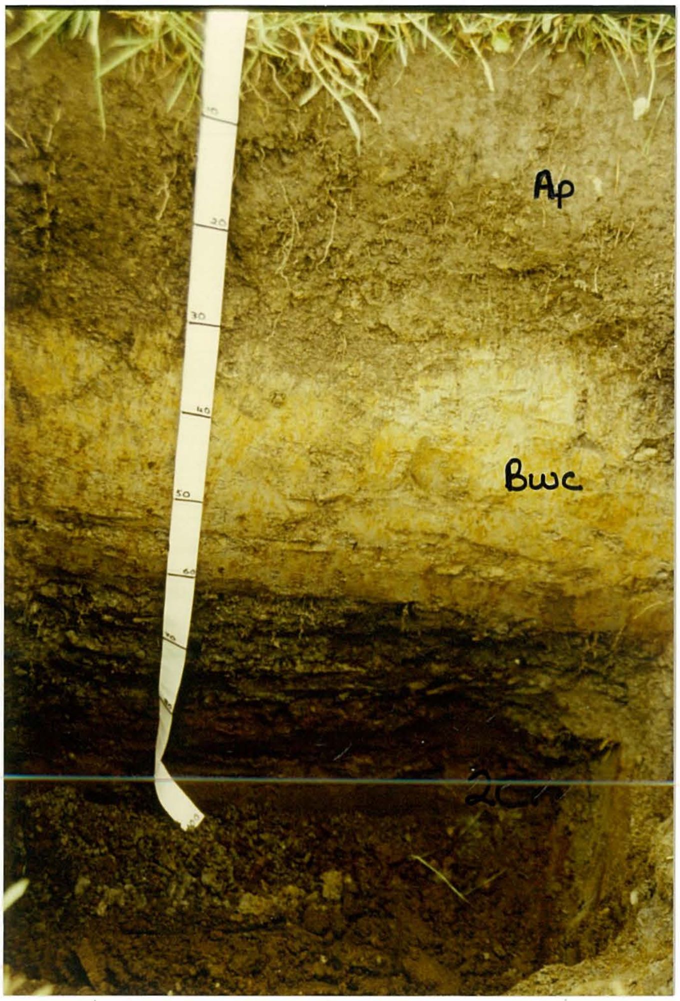


Plate 23 Ahikouka silty clay loam on sand

Soils have a thick dark friable topsoil, over dull yellowish-brown and bright brown mottled B horizons with medium nut and block structure. The B horizions typically contain concretions and overlie sands and/or grits and gravels that contain low chroma mottles at depths of more than 45cm.

main limitation to its intensive usage is the poor natural drainage, followed by lack of nutrients, both of which can be readily corrected.

AHIKOUKA STONY SILTY CLAY LOAM.

Ahikouka stony silty clay loam is a slowly accumulating gley recent soil described for the first time in this survey. These soils have a brownish black friable A horizon with moderately developed medium nut and block structure; over a greyish yellow brown B horizon (containing concretions) with moderately developed coarse nut and block structure; overlying unstructured grey and brown mottled stony sand, and coarse sands with occasional lenses or layer of clay. The presence of stony layers within the profile distinguishes this soil from the other Ahikouka soils.

Ahikouka stony loam silty clay loam (plate 24) is found on the imperfectly drained slowly accumulating flood plain of the Ruamahanga River, formed in alluvial silts, sands and gravel. These soils are found in the area around the junction of Judds road with Kahutara road.

Ahikouka stony loam was mapped previously as Tukituki sand loam, stony gravel etc. (New Zealand Soil Bureau, 1954), and as Pukeo clay loam (Heine, 1975) (see appendix 2). The positions of Pukeo clay loam and Ahikouka clay loam were apparently reversed on the map accompanying Soil Bureau Record 40 (Heine, 1975), as the description of Ahikouka silt loam matches that of the soils found in this survey (Appendices 2,3 & 4). Ahikouka stony loam shows a wide range of variation from very stony soils similar to Te Pare stony silty clay loam, and at the other extreme, very like Ahikouka silty clay loam on sand but with thin lenses of stones in the profile. The most important part of the soil in determining agricultural and horticultural practices is the top 40cm. and as this section closely resembles Ahikouka silt loam on sand, it was decided to name the soil Ahikouka stony loam.

This soil is mapped as one member of a complex along with Te Pare stony silty clay loam (see appendix 5 and the soil map). The two interchange in a complicated way with no obvious pattern and cannot be shown separately at a scale of 1;25 000.

They are soils of high potential value for food production, the main limitations being natural drainage and fertility, both of which can be changed. Stones are too deep in the horizon (greater than 40cm) to affect normal farming practices, i.e. ploughing.

TE PARE STONY SILTY CLAY LOAM

Te Pare stony silty clay loam is a slowly accumulating gleyed recent soil identified for the first time in this survey. Soils have brownish black friable A horizons with moderately developed medium nut structure; over subsoils which are stony by 20cm, although few or no stones may be present below 40-50cm. Stones are often less than one to two centimetres in size.

Te Pare stony silty clay loam (plate 25) is found on the slowly accumulating flood plain of the Ruamahanga River, developed in alluvium. They are found in an area around the junction of Judds Road with Kahutara Road (see soil map).

Te Pare stony silty clay loam has been previously mapped as Tukituki stony loam etc. (New Zealand Soil Bureau, 1954), and as Pukeo clay loam (Heine,1975); (see appendix 2). Pukeo clay loam and Ahikouka silt loam were apparently transposed on the map accompanying Soil Bureau Record 40 (Heine, 1975), and so should show Ahikouka silt loam in this area. As this soil is closely linked to Ahikouka stony silty clay loam which is in turn related to Ahikouka silty clay loam, it was thought that this stony soil should receive a local name, rather than Tukituki stony loam.

Te Pare stony silty clay loam and Ahikouka stony loam form a mosaic over a portion of the slowly accumulating flood plain and cannot be separated

Plate 25 Te Pare stony silty clay loam

Soils are characterised by a stony to very stony layer at depths of less than 20 cm, directly below the A horizon. Topsoils are generally brownish black, friable sandy clay loam soils with moderately developed medium nut structure. If the profiles are stony throughout, the B horizons have weak nut and crumb structure between stones.

from each other at the scale of mapping (1:25 000). For this reason they have been mapped together as a complex,(Ah2 + Tp) (see appendix 5 and the soil map).

Te Pare stony silty clay loam is of moderate value for food production, limited by the shallow stony profiles. Stoniness doesn't however affect pasture growth the way it limits cropping, horticulture and forestry. The only limitation on pasture growth is that of dryness due to the shallowness of the profiles, and of natural fertility. Both of these limitations can be overcome. These soils provide suitable places for housing or other farm buildings.

3.3.3 Soils of the rapidly accumulating flood plain.

ONOKE SILTY CLAY

Onoke silty clay is a rapidly accumulating gley recent soil. Profiles have a thin brownish black topsoil with weak structure, over olive brown, yellowish brown and light grey mottled massive subsoils.

These soils have developed in alluvium which was dumped on low lying land as tailings during the excavation of the Ruamahanga River diversion channel (plate 26). The silty profiles overlie gravelly material heaped into mounds, which are also tailings. The depth of the silt dominated layer varies from about 30cm to more than one metre (plate 27).

The limitations and potentials of these soils were not assessed as the area found during this survey was very small.

These soils were previously described by Heine (1975), and though they were not shown within the study area it was noted in the extended legend that they are found in association with Pukeo clay loam.

Plate 26 Dredge Tailings

These dune-like forms were created by the dumping of dredge tailings which were excavated during the Ruamahanga River diversion.

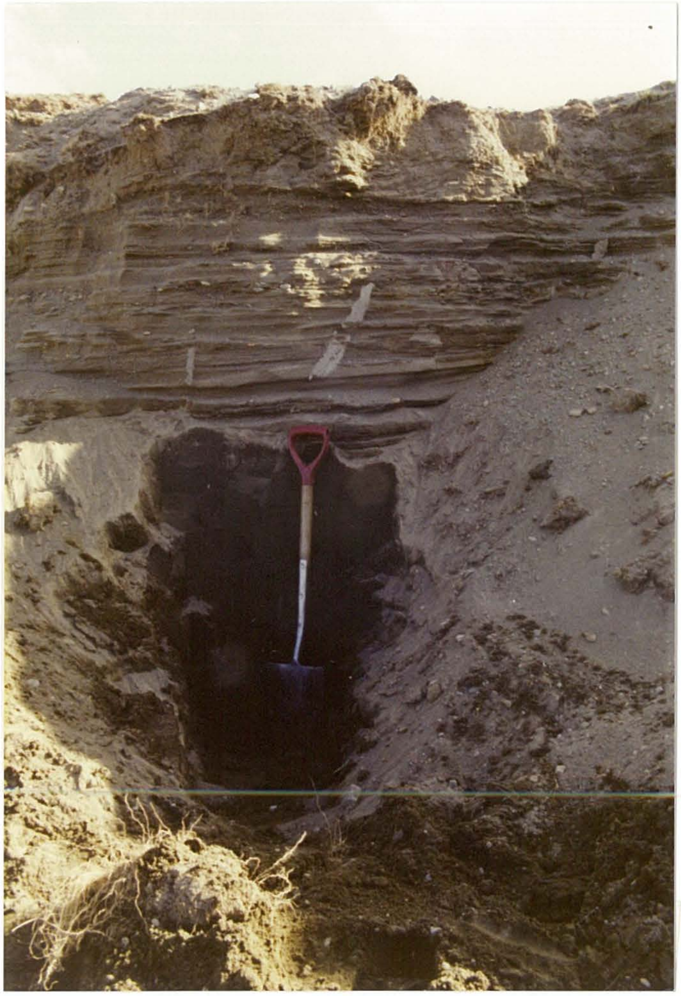


Plate 27 Onoke silty clay

The dredge tailings excavated during the diversion of the Ruamahanga River were deposited in only one location in the study area. The photo above shows the deposits created in this manner. Note that the 30 cm of material which overlies the coarser deposits can be over one metre deep in places and are the parent material in which Onoke silty clay soils have formed.

Only one small area of Onoke silt loam was recognised in this survey, alongside the Ruamahanga River channel, and has been shown on the map as a simple mapping unit.

PUKEO CLAY LOAM

Pukeo clay loam is a rapidly accumulating gleyed recent soil. Profiles characteristically have greyish yellow brown to brownish black friable often mottled A horizons , which can range in texture from silty clay to fine sandy clay loam and have moderately to strongly developed coarse nuts breaking to medium nut and crumb structure; over yellowish grey and yellowish brown mottled AC horizons. These overlie very firm and massive olive grey and yellowish brown mottled silt and clay dominated sediments. Textures may grade to include fine sands in areas near the river channel. Low chroma colours are common in the profile, as are ochreous stains along the insides of root channels. In places thin peat lenses are found between depths of approximately 45-70cm, and the silt and clay sediments may overlie more sandy textured sediments at depth, i.e. at more than 80-90cm.

Pukeo clay loam soils (plate 28) are developed in alluvium deposited by flooding of the Ruamahanga River, and is found on the low lying rapidly accumulating flood plains close to the river and lake.

Pukeo clay loam was mapped previously by New Zealand Soil Bureau (1954) and Heine (1975) as Kairanga silt loam and clay loam, and Ahikouka silt loam and Martinborough loam respectively (see Appendix 2). Martinborough loam has a structured B horizon and was not found in this survey; and as Pukeo clay loan and Ahikouka silt loam were apparently transposed on the map accompanying Soil Bureau Record 40 (Heine 1975), the positions of the two soils have been reversed in this survey. As the soil profile descriptions match, the name Pukeo clay loam was retained. Pukeo clay loam covers an extensive area and was mapped as a simple mapping unit (see appendix 5 and the soil map).

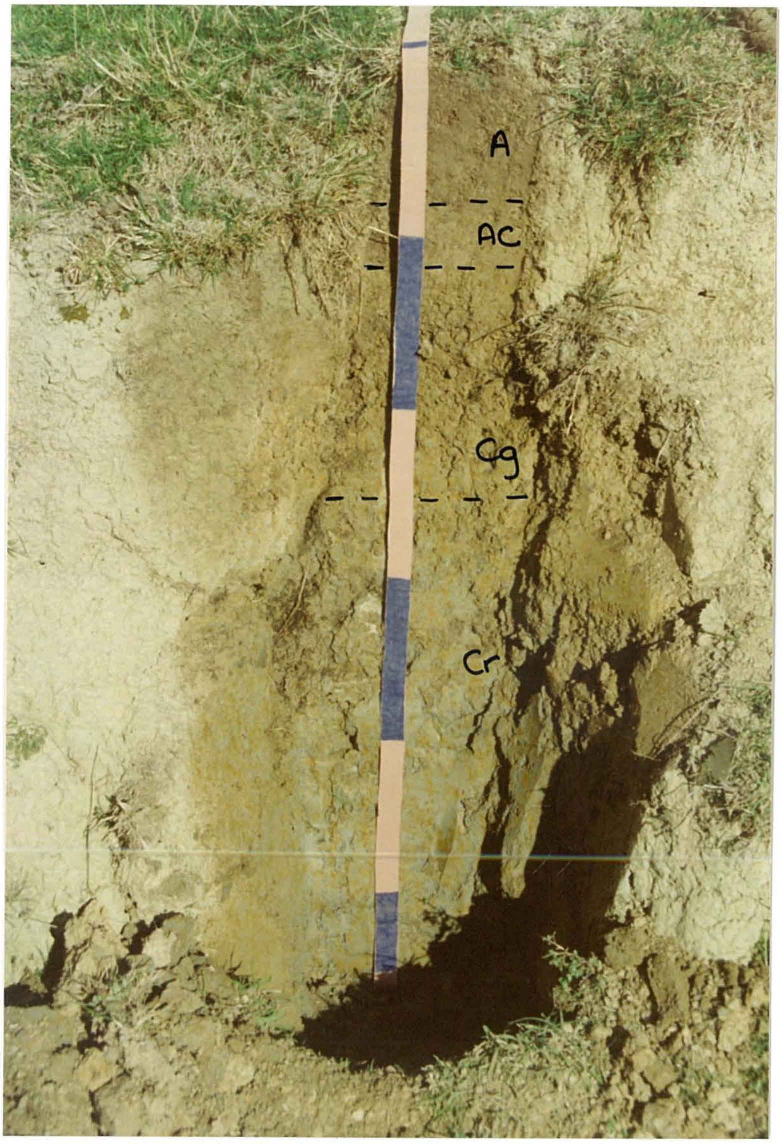


Plate 28 Pukeo clay loam

Soils have A/C horizons which have low chroma mottles at depths of less the 45cm. Silt and clay textures dominate throughout the profile, although sandy clay loam textures may occur at depth. Cracking of the upper solum in the summer, and the ploughing of the very firm material may lead to the appearance of very coarse nut and block structure.

Soils are of moderate value for food production, being limited by the poor natural drainage and lack of subsoil structure. Soils in lower parts of the landscape pond water in the winter for considerable periods after rain as drainage is very slow, and in the late summer when dry they crack at the surface and the subsoil becomes very hard. These soils are not suited to forestry (unless water tolerant species are chosen), or horticulture but provide good pasture growth and can be used for cropping. Soils are presently used for both these purposes. The soils are ploughed and planted in barley for three to five years before sowing pasture. The improved ryegrass clover pasture is grazed by sheep and both dairy and beef cattle. Areas not yet claimed for more intensive production offer rougher grazing for beef cattle and sheep.

PUKEO CLAY LOAM ON SAND.

Pukeo clay loam on sand is a rapidly accumulating gleyed recent soil identified for the first time in this survey. Profiles have a dull yellowish brown friable topsoil with moderately developed fine to medium nut and crumb structure; over olive grey and yellowish brown mottled sediments. These contain repetitive sand/sandy clay/ clay layering, the sandy layer being the thickest and the clay layer the thinnest. The layered sediments overlie bluish fine sandy clay material which is generally found between one and one and a half metres depth. This blue material is 'sensitive', that is when disturbed it exudes pore water, loosing coherence and slumping into the pit. When put on a spade blade then thumped against the ground, the sediment feels like liver to the touch.

Pukeo clay loam on sand is found on the rapidly accumulating flood plains of the Ruamahanga River in poorly drained sites close to where the river discharged into Lake Wairarapa (plate 29), developed in sediments deposited by flood events.

Pukeo clay loam on sand was previously mapped by New Zealand Soil Bureau (1954) and Heine (1975) as Manawatu loam and Ruamahanga sand

Plate 29 Ruamahanga River delta

The land around the former mouth of the Ruamahanga river is the most recently deposited subearial part of the delta. The sediments are characterised by a silty layer overlying more sandy deposits, and form the parent material for the soil Pukeo clay loam on sand.

respectively (see Appendix 2). These soils resemble Pukeo clay loam in the upper part of the profile, differing in having the layered sediments in the lower part of the profile, therefore it was decided to name them Pukeo clay loam on sand.

Pukeo clay loam on sand soils (plate 30) have been mapped alone in a simple mapping unit.

They are soils of moderate value to food production limited by the poor natural drainage, lack of subsoil structure and risk of flooding. They are best suited to pasture production or cropping, and are presently used for these purposes. Improved ryegrass clover pasture is grazed by sheep and beef cattle.

TE HOPAI CLAY LOAM.

Te Hopai clay loam is a rapidly accumulating gleyed recent soil described for the first time in this survey. Soils have greyish yellow, yellowish grey and yellowish brown mottled silty clay and clay textured profiles which are massive or have very weak coarse blocky structure. Litter layers may sit on the surface and mixing caused by pugging can produce local dark areas at the surface,, but there is no recognisable A horizon development. Fresh water mussel shell fragments are commonly found between the depths of 30-50cm, and thin peat lenses may be found at about 60cm depth.

These soils are found in the beds of recently drained lagoons, some of which were once permanent features, other ephemeral (plate 31). Sites are poorly to very poorly drained, and even in summer the water table is often less than one metre below the surface and may be as close as 30cm. In winter rainfall can pond for weeks or months.

Te Hopai clay soils (plate 32) have not been described before as at the time of previous surveys they were under water. Te Hopai clay loam has been mapped in a simple mapping unit (see appendix 5 and the soil map).

Plate 30 Pukeo clay loam on sand

Pukeo clay loam on sand soils have an A/C profile with low chroma mottling at depths of less than 45 cm. Friable, dull yellowish-brown, silty clay loam topsoils with strongly developed fine-medium nut and crumb structure, overlies olive-grey and yellowish-brown massive subsoils. The subsoils are composed of deltaic sediments which have characteristic sand/sandy clay/clay layering at depths greater than 50-60 cm.

Plate 31 Former bed of Te Hopai Lagoon

In the above photo a cliff approximately one metre high marks the boundary between Pukeo clay loam soils on the higher ground to the right, and Te Hopai clay soils on the lower land to the left. Te Hopai clay soils have formed in the lacustrine silts and clays of former lagoon beds. The cliff previously marked the eastern edge of Te Hopai Lagoon.

Plate 32 Te Hopai Clay

Te Hopai clay soils are developed in very poorly drained lacustrine silts and clays. Profiles are characterised by the lack of a topsoil, textures dominated by silts and clays and low chroma colours which reach to the surface. A few centimetres of darkened soil may be present at the surface where pugging has mixed litter with the soil. Freshwater mussel shells are often found at depths of between 30 and 50 cm.

Te Hopai clay loam is of low value for food production due to its very poor natural drainage and lack of structure. It is best used as summer pasture. There is less chance of pugging in summer months, and because of the high water table, plants have access to soil water for much longer than those on other local soils. These soils presently provide rough grazing for sheep and cattle.

TE HOPAI SANDY CLAY.

Te Hopai sand clay loam is a rapidly accumulating gley recent soil described for the first time in this survey. Profiles lack topsoils, having olive grey, yellowish brown and bright yellowish brown mottled silty sediments over sandy sediments. Litter layers are common at the surface but these have not yet been incorporated into the soil to form a darkened friable A horizon. Profiles may contain the remains of freshwater mussel shells, typically at 30-40cm sitting over sand and buried by silty alluvium. Muds and sands deep in the profile (deeper than 60cm) may show unmottled greenish grey and blue colours.

Te Hopai sandy clay soils are found in very poorly drained localised hollows and low lying areas on the rapidly accumulating flood plain of the Ruamahanga River. They were previously the beds of small lagoons and swampy areas which have been artificially drained over the last five to ten years. Many of them pond water during winter months (plate 33).

Te Hopai sandy clay has not been described prior to this survey as soils were not drained at the time. Te Hopai sandy clay has been mapped as a simple mapping unit.

These soils are of low value for food production. The very poor natural drainage of the soils means that even through the summer the water table may be less than one metre below the surface. Water from rain and from the drainage of higher ground collects in these locations during wet winter

Plate 33 Ephemeral pond.

Te Hopai sandy clay loam soils are found in locations which pond water through the winter months. The shallow ephemeral ponds dry out in summer allowing pasture to grow, however even in summer the water table is often found at depths of < 1m.

months. Care needs to be taken with pasture on these soils to prevent pugging. They are currently in pasture, used as grazing for sheep and cattle.

LAKE SHORE SAND.

Lake shore sand is a rapidly accumulating recent soil. Profiles lack structured topsoil, having approximately 8cm greyish olive sand, over grey and greyish olive sand. They may be unmottled or show common olive brown mottling. Some overlie dark olive grey to greenish grey sands at depths greater than 80cm. These are often 'sensitive'.

Lake shore sand is found along the lake margin, on the poorly drained sandbanks which have formed there (plate 34) (see physiographic units map). These sandbanks are exposed during dry spells and can be several hundred metres wide when lake levels are low. In contrast, during wet winter months lake levels are generally high and only a narrow strip, if any of the sandbank is free of water.

These soils were previously mapped as Esk sand (New Zealand Soil Bureau, 1954), and Ruamahanga sand (Heine, 1975), (Appendix 2). Profiles described in this survey (see appendix 4) do not have topsoils, and therefore the name Lake shore sand has been used to distinguish these deposits from Ruamahanga sand soils. Lake shore sand soils has been mapped using a simple mapping unit.

These soils are of low value for food production. Their usefulness is limited by poor drainage which is not easily improved because of low elevation, frequency of flooding and lack of structure. Currently, they are being used for extensive grazing of beef cattle and sheep over summer months.

Plate 34 The eastern lake margin

Lake shore sand is found along the eastern lake margins on the low wide sandbanks. The area of the sandbanks varies with the season and weather, with much of their width being inundated by high lake levels.

Table V Correlation and classification of soils defined in previous surveys to those described in the current survey.

Map Symbol	SPC[1]	Soil Bureau Record 40 revised.	Correlation to Original Set.	NZ Soil Groups.	This Survey.	Classification by USDA Taxonomy. To Subgroup (To Family)
SOILS OF THE SAND DUNES.						
Ka	M	Manihera sand	Patea sand, 23.	Moderately leached central YBS.	Kahutara sand.	Typic Ustipsamment (sandy, mixed, mesic)
Wo1	B	Manihera sand	Patea sand, 23.	Moderately leached central YBS.	Wairio sand.	Typic Ustipsamment (sandy, mixed, mesic)
Wo2	C	Manihera sand	Patea sand, 23.	Moderately leached central YBS.	Wairio mottled sand.	Aquic Ustipsamment (sandy, mixed, mesic)
Mt	D	Kumenga mottled sand	Whananaki sand, 23b.	Moderately leached gleyed central YBS.	Mangatete sand.	Mollic Psammaquent (sandy, mixed, mesic)
Mn1	X	Manihera sand	Patea sand, 23.	Moderately leached central YBS.	Manihera sand.	Typic Ustipsamment (sandy, mixed, mesic)
Mn2	Q	Manihera sand	Patea sand, 23.	Moderately leached central YBS.	Manihera mottled sand.	Aquic Ustipsamment (sandy, mixed, mesic)
Pa	V	Manihera sand	Loose sand dunes	Moderately leached central YBS.	Parera sand.	Typic Ustipsamment (sandy, mixed, mesic)
Kg1	Z	Kumenga mottled sand	Whananaki sand, 23b.	Moderately leached gleyed central YBS.	Kumenga mottled sand, dune phase.	Mollic Psammaquent (sandy, mixed, mesic)
Kg2	W	Kumenga mottled sand	Whananaki sand, 23b.	Moderately leached gleyed central YBS.	Kumenga mottled sand, swale phase	Mollic Psammaquent (sandy, mixed, mesic)
SOILS OF THE SLOWLY ACCUMULATING FLOODPLAIN.						
Ak1	P	Ahikouka silt loam[2]	Manawatu silt loam etc, 1	Gley recent soil from alluvium.	Ahikouka silty clay loam	Aeric Haplaquept (fine loamy, mixed, mesic)
Ak2	L	Ahikouka silt loam	Tukituki stony gravel etc, 1	Gley recent soil from alluvium.	Ahikouka stony silty clay loam	Humic Haplaquept (coarse loamy, mixed, mesic)
Tp	G	Ahikouka silt loam	Manawatu silt loam etc, 1	Gley recent soil from alluvium.	Te Pare stony silty clay loam	Humic Haplaquept (sandy - sandy skeletal, mixed, mesic)
Ak3	K	Ahikouka silt loam	Tukituki stony gravel etc, 1	Gley recent soil from alluvium.	Ahikouka silty clay loam on sand	Aeric Haplaquept (fine loamy over sand, mixed, mesic)
SOILS OF THE RAPIDLY ACCUMULATING FLOODPLAIN						
Pu1	I	Pukeo clay loam[2]	Kairanga loam etc, 2a.	Gley recent soil from alluvium.	Pukeo clay loam	Typic Fluvaquent (fine clayey, mixed, mesic)
Pu2	T	Ruamahanga sand	Esk sand, 1b.	Gley recent soil from alluvium.	Pukeo clay loam on sand	Typic Fluvaquent (fine loamy over sandy, mixed, mesic)
Th1	J	NA	NA	Saline gleyed recent soil.	Te Hopai clay	Typic Haplaquent (fine clayey, mixed, mesic)
Th2	E	NA	NA	Saline gleyed recent soil.	Te Hopai sandy clay	Typic Haplaquent (fine loamy, mixed, mesic)
On	A	Onoke silty clay	Mercer loam etc,2c.	Saline gleyed recent soil.	Onoke silty clay	Aquic Ustifluvent (fine silty, over skeletal, mixed, mesic)
S	S	Ruamahanga sand	Lake shore sand.	Gley recent soil from alluvium.	Lake shore sand	Typic Psammaquent (sandy, mixed, mesic)
Mn3	H	Kumenga mottled sand	Whananaki sand, 23b.	Moderately leached gleyed central YBS.	Kumenga mottled sand on silty clay.	Aeric Haplaquent (sandy over loamy, mixed, mesic)

[1] SPC - Soil Profile Class

[2] The soils Ahikouka silt loam and Pukeo clay loam were transposed on the map accompanying Soil Bureau Record 40.

3.4.0 Summary and discussion of soil properties

Information derived from the morphology and distribution of soils can be used to help interpret the history of the infilling of the estuary and Lake Wairarapa. The sequence of soil development on the dune crests is particularly useful.

In this section characteristic properties of the three main soil groups represented in the study area (yellow-brown sands, recent soils and gleyed recent soils) will be discussed and related to those of the specific soils mapped in this study.

A few chemical tests were carried out on samples from the main soil groups. The tests selected, methods and results are reported in chapter four.

3.4.1 Yellow-brown sands

The yellow-brown sands are formed on sand drifts of various ages along coasts and the edges of lakes and large rivers. They are regarded as an intrazonal group because of their youth, and the coarse sandy texture of their parent material (Cowie 1962A, Gibbs 1980, Claridge 1977). Their youth means that they have not had sufficient time to develop the characteristics of the surrounding zonal soils. The coarse texture influences the soil physical and chemical properties and thus the soil forming processes.

The yellow-brown sands have a wide range of mineralogy but texture is more important than composition especially in the initial stages of soil formation. The small percentage of clay particles in the inorganic fraction allows the effects of soil processes to be readily impressed on the soil body, changes in the profile being rapid and well marked (Claridge 1961, Cowie 1962B, Cowie 1977, Gradwell 1977).

YELLOW-BROWN SANDS IN THE MANAWATU

In the Manawatu, yellow-brown sands have been studied in detail, and four distinct dune building phases have been recognised and the soils of each dune complex described (Claridge 1961, Cowie 1962a, Cowie 1962b, Cowie 1963, Cowie *et al* 1967, Cowie 1977). Dune formation was discontinuous as evidenced by the lack of a gradual transition of soil development from the younger to older dunes. Boundaries between the four phases are abrupt (Cowie *et al* 1967, Cowie 1968). The ages of the dune phases are considered to be;

Koputaroa phase	10 000 - 20 000 years BP
Foxton phase	2 000 - 4 000 years BP
Motuiti phase	500 - 1 000 years BP
Waitarere phase	0 - 100 years BP

The soils are necessarily younger than the dunes on which they are formed, as an interval has to be allowed for the colonisation of the dunes by stabilising vegetation, and the initiation of soil development (Cowie 1962a, Cowie et al 1967, Cowie 1968).

Soils on the dunes and associated sand-flats show a progressive increase in profile development with increasing age (Cowie 1968, Cowie 1977). Both A and B horizons thicken through the sequence. A horizon thicknesses increase through such processes as worm mixing and the eluviation of humus. The darkening of the B horizon with increasing age is due to the release of iron oxides from minerals by weathering. In permanently wet soils gleying occurs as iron is reduced, forming characteristic yellowish-grey to blue-grey colours. In soils with intermittent water logging a zone of mottles forms where both oxidised and reduced forms of iron coexist. With time the reddish Fe-Mn mottles harden to form concretions, it is thought that this process takes about 2-3 000 years.

As weathering releases nutrients they are progressively leached out of the soil. The rate of leaching is rapid at first then slows until the rate of leaching is balanced by the rate of weathering. In soils of the same age, a poorly drained soil will be less leached than a well drained soil.

Subsoils become more compact with increasing age and this is thought to represent the formation of an incipient fragipan.

YELLOW-BROWN SANDS OF THE STUDY AREA

The yellow-brown sands of the study area follow a similar pattern of soil profile development to those found in the Manwatu.

The dune lines from oldest to youngest are ;

dune line 1 - Kahutara phase,
dune line 2 - Wairio phase,
dune line 3 - Manihera phase,
dune line 4 - Parera phase.

Soil profiles deepen and individual horizons thicken and become more well developed with increasing age. Thus the youngest soil on dune line 4 has an AC profile, the A horizon is only a few centimetres thick with a very weak crumb structure. Soils on dune set 3 have a thicker darker A horizon with better developed structure, and there is often a transitional AC horizon below it. Soils on dune line 2 have well developed A horizons, and soil forming processes have been acting long enough for a Bw horizon with weak coarse structure to have formed. Soils on the oldest dunes, dune line 1, have not only A and B horizons but also a transitional BC horizon. Sandy subsoils become increasingly compact with age, the loose sand of dune line 4 is much easier to dig than the firmer subsoils of dune line 1. As in the Manawatu the zonal soils developed in the surrounding area are yellow grey earths, and it may be that given sufficient time, an incipient fragipan may develop in the upper part of the C horizon.

The physiographic positions of the dune lines and the profile development of the soils formed on them indicates that, as in the Manawatu, dune formation was discontinuous.

COMPARISON OF THE YELLOW-BROWN SANDS OF THE TWO AREAS

Full profile descriptions of the dune soils within the study area are found in appendix 4, and briefer descriptions with accompanying photographs in section 3.3.1. Profile descriptions for the dune soils of the Manawatu are taken from Cowie 1963, Cowie *et al* 1967 and Cowie 1968.

Waitarere sand is the youngest dune soil in the Manawatu formed on the dunes of the Waitarere phase. Waitarere dunes cover European artifacts and are therefore less than 120 years old (Cowie 1963). Soil forming processes have had little time to affect the sand, and profile development is limited to a darkening of the top inch or so by decomposing plant remains (Cowie *et al* 1967). The age of the Waitarere soils has been estimated at less than 60 years (Cowie 1968). The description of these soils is very similar to that of the youngest dune soil from the study area, Parera sand. Parera sand soils have a thin A horizon with very weakly developed crumb structure over loose sand. The similarity of the soils suggests that they are of a comparable age, the dunes being approximately 120 years old, and the soils developed in them closer to 60 years of age.

In the Manawatu the Motuiti dune phase is the next oldest, estimated at between 500 and 1 000 years old. The advance of the dunes is attributed to destruction of the vegetation on previously stabilised dunes by the Maori (Cowie 1963). The soil which has developed in these dunes, Foxton dark grey sand (or Motuiti dark grey sand), has a very dark grey to black topsoil up to 15cm deep, over 5 to 12cm of brown loose sand, which grades down into grey, loose sand (Cowie et al 1967, Cowie 1963). The soils have been estimated to have ages ranging from 500 - 750 years old.

These profiles sound similar to those Manihera sand soils on dune line 3 which have dark brown friable A horizons and a transitional AC horizon over loose yellowish brown sand; and also to Wairio sand soils which have dark friable A horizons over weakly developed dull yellowish brown to brown B horizons overlying loose yellowish brown sand.
Manihera sand soils are younger than a peat layer dated at 590 ± 60 years and could therefore be of a similar age to the younger soils of the Motuiti phase. The Wairio soils have structured subsoils and are therefore somewhat older than the soils on the Motuiti dunes.

The next oldest dune soil in the Manawatu is the Foxton black sand, which has developed in the dunes of the Foxton dune phase estimated to be between 2-4 000 years old. The cause of the accumulation of these dunes is not known (Cowie 1963). The Foxton black sand soils are estimated to have an average age of 3 000 years (Cowie 1968). The soils have a well defined black topsoil 25 to 30 cm thick, overlying a slightly firm yellowish brown to brown subsoil, which grades down into a loose grey sand (Cowie 1963, Cowie *et al* 1967). The descriptions of Wairio sand are very similar, although the topsoils are not usually black but dark brown. As dune line 2 (in which Wairio sand soils have formed) has advanced over a surface which has a maximum age of 3 500 to 3 600 years BP the dune soils would have a maximum age of about 3 000 years.

The oldest dune soils in the Manawatu are the Koputaroa sandy loam soils developed in the dune sand of the Koputaroa phase. The dune phase is estimated to be from 10 000 to 20 000 years old and the soils to have an average age of 15 000 years. The oldest dune line within the study area is much younger than this as the dune sands are draped over a cliff cut by the Holocene marine transgression which culminated approximately 6 500 years ago. Thus the soil of dune line 1, Kahutara sand is likely to be have a maximum age of about 6 000 years.

3.4.2 Recent soils and gleyed recent soils

Recent soils are those found on parent material which was recently deposited or is still accumulating, and have either AC or ABwC horizon nomenclature. They are azonal, lacking the horizonation of zonal soils (Mew and Brophy 1972, Gibbs 1980, Rijkse 1985, Whitten 1985).

Rijkse (1985) lists the following classes of recent soils distinguished by the New Zealand Genetic Classification;

- Recent soils from slowly, moderately or rapidly accumulating;
  - alluvium
  - colluvium
  - wind blown sand
  - loess
- Gleyed recent soils from slowly, moderately or rapidly accumulating;
  - alluvium
  - colluvium
- Recent soils from volcanic ash; and
- Saline gley recent soils.

As all the accumulating soils within the study area experience long periods of wetness (or would do if not artificially drained) they are gleyed recent soils.

CHARACTERISTIC PROFILE FEATURES

Recent soils are too young to have undergone soil forming processes, hence their limited profile development. A common characteristic is the limitation of horizon development to an A horizon, these generally become thicker and more distinct as the intervals between deposition of material increases. Very thin and/or buried topsoils are often found in sites which are subject to frequent additions of fresh material (Mew and Brophy 1972, Rijkse 1985, Whitten 1985).

Gley recent soils are subject to flooding and their profiles, especially the subsoils, reflect the process of reduction. The soils may be described as weakly, moderately or strongly gleyed (Rijkse 1978).

Where gleying is strongest, homogenous grey colours prevail, showing the horizon to be subject to prolonged saturation. Parts of the soil body which undergo alternate periods of oxidation and reduction (such as soils which undergo seasonal water table fluctuations), develop ochreous mottles. These may be in a pale brown or grey background. Iron cutans in large pores and root channels are associated with short periods of saturation, and long periods in which the soil is close to saturation (Buol *et al* 1980, Gibbs 1980)

PARENT MATERIALS

Because they are too young for substantial modification to have occurred, the mineralogy, chemistry and physical properties of recent soils reflect that of their parent material (Gradwell 1985, Whitten 1985).

Gley recent soils have a wide range of parent materials, therefore their textures, mineralogy, chemistry and physical properties also vary widely (Mew and Brophy 1972, Gibbs 1980). In the study area the recent soils and gleyed recent soils have all formed on slowly to rapidly accumulating alluvium deposited by the Ruamahanga River. The quartzo-feldspathic parent material is derived from the greywacke and argillite Rimutaka, Tararua and Aorangi Ranges, and the Tertiary marine sediments which flank the latter.

The texture of alluvium, and so of soils developed in it is very variable and can change rapidly over short distances. Textures may be compared to those of deposits in modern braided river channels (Mew and Brophy 1972, Gradwell 1985).

In the study area recent soils such as Te Hopai silt loam and Pukeo clay loam show very little variation in texture both in profile and across the landscape. In contrast, others such as the Ahikouka series show marked and rapid changes in texture.

Ahikouka silty clay loam over sand has a sharp textural boundary within its profile, silty to fine sandy clay loams overlying coarse sands and grits at about 60cm (unit 7, section 2.2.2). Thin lenses of small stones may be found within the silty to sandy clay loam horizon. Ahikouka silty clay loam over sand grades into Akikouka stony silty clay loam, which, along with Te Pare stony loam is a member of the Ak2 + Tp complex (see appendix 5 in the back pocket). Within this complex the depth to stones may change rapidly over short distances, as may the percentage of stones found at a particular depth. In places the stones may be so abundant that they touch, the spaces being filled by sand and finer material. Nearby the stones may only constitute a few percent of the total soil body.

The presence of stones within a soil body has the effect of reducing its water-holding capacity. In effect stones occupy space which would otherwise contain pores capable of storing water, meaning less available water for plants. Gravel or coarse sand with little storage for water in the deeper part of the soil reduces the water supply of the profile (Gradwell 1985). However loamy soil which overlies a coarse textured layer such as coarse sand or gravel stores more water at field capacity[1] than its uniform equivalent. The amount of water held by the loamy layer increases as the underlying coarse layer becomes coarser, and decreases with elevation above the textural boundary. Most of the increased storage in such layered soils is in the region immediately above the interface (Clothier *et al* 1977).

[1] Field capacity refers to the amount of water stored in the soil when profile drainage has effectively ceased after saturation.

Soils which are layered are particularly valuable for agriculture as they are relatively free draining in the saturated state, and impede the flow of water when unsaturated (Clothier *et al* 1977). There would be little loss of water via deep percolation when irrigating, as long as soils were not saturated. Soils would drain rapidly when wet, and hold water when drier. The formation of iron accumulations and mottling immediately above the interface indicates that the soil is near saturation there for significant periods of time (Veneman *et al* 1976).

Ahikouka silty clay loam on sand soils have a mottled loamy B horizon containing concretions which overlies coarse sand. Ironstone may form immediately above the textural boundary, and is commonly found in sites near the base of dune set 2. Mottles, concretions and ironstone all typically form in zones of intermittent waterlogging, accentuated here by the storage of water in the area above the textural discontinuity. Ahikouka stony silty clay loam soils may also contain concretions in loamy layers above or between layers of gravels. Thin iron pans (< 1-2mm thick) have formed in places at the top of the stony layers. Iron in the reduced state would be transported to the boundary, and accumulate there as the water held at the boundary was utilised by plants, the conditions becoming increasingly oxidising.

PHYSICAL AND CHEMICAL PROPERTIES

The chemistry of recent soils reflects their immature nature, they are generally weakly leached with no appreciable translations of minerals and little organic matter build up (Searle 1985, Whitten 1985). Gleyed recent soils are weakly leached and tend to have slightly higher fertility levels than associated freely draining soils (Gibbs 1980).

Horizons should not have had the time to develop compactness and should therefore hold reasonable volumes of air and water and offer little impediment to roots (Gradwell 1985).

DISCUSSION OF SOIL PROPERTIES WITHIN THE STUDY AREA

There are three main divisions that can be made of the gleyed recent soils within the study area on the basis of profile development and drainage.

The soils of the Ahikouka series show greater soil profile development than the other gley recent soils, the Ahikouka soils all having moderately developed B horizons. The lack of layering of sediments within the subsoil, and the generally thick well structured A horizons show that accumulation is occurring at a relatively slow rate. The presence of structure in the B horizon also shows that these soils are older than other gleyed recent soils within the study area. Ahikouka silty clay loam on sand is older than dune line 2, as evidenced by the burial of the soil by dune sand in a profile exposed in the Oporua floodway (plate 5).

The other gleyed recent soils all lack structured subsoils. All these low lying poorly developed soils are very wet for periods of time, ponding water, but some undergo reducing conditions for most of the year.

Pukeo clay loam and Pukeo clay loam on sand as well as Kumenga sand - swale phase are moderately gleyed soils. All have more than 3% low chroma mottles to within half a metre of the surface, and are generally dominated by low chroma colours and ochreous mottles to the surface. These soils show evidence of layering in their subsoils which is most strongly marked in Pukeo clay loam on sand soils (plate 30). This layering and the lack of subsoil structure indicates the youth of these soils. Pukeo clay loam soils often have ochreous linings within root channels showing that the soil is nearly saturated for long periods.

The third group of soils are the strongly gleyed Te Hopai clay, Te Hopai sandy clay and Lake shore sand. These soils are all frequently inundated by water and may remain saturated, with resulting reducing conditions for long periods of time. The soils of the Te Hopai series occupy hollows and basins, and pond water throughout the winter and spring (plate 33). The water table is close to the surface throughout the year (plate 32). Lake shore sand is found on the sandbanks of the lake margin and can be flooded by high lake levels many times a year. The youth of these soils is reflected in their common lack of a topsoil.

CHAPTER FOUR: LABORATORY WORK.

4.1.0 Introduction.

As stated in section 1.1.0, the aims and scope of the study, the primary aim was to map the late Quaternary deposits within the study area. The information provided by the distribution and characteristics of these deposits could then be used to interpret the history of infilling of Lake Wairarapa. Specific aims were to produce a soil map, paying particular attention to the chronosequence of sand dunes in the area. Soils were defined and described by characteristics which are easily identified in the field such as colour, texture and structure.

It was decided to carry out a few chemical analyses to reveal trends in soils which could assist with classification and/or interpretation of the soil pattern. Previous studies of sand dune chronosequences have found certain chemical analyses to follow trends with increasing age, and to be of use when considering the agricultural potential of soils, i.e. C% and fractions of phosphorous by Syers and Walker (1969A, 1969B).

The following chemical analyses were carried out as part of this study;

(1) pH in H_2O, KCl and $CaCl_2$

(2) carbon %

(3) nitrogen %

(4) phosphorous - non-occluded inorganic
- organic
- total.

4.1.1 Sampling procedure

Once the soil map was completed soils were sampled for chemical analysis. Sites for sampling were selected to represent a particular soil profile class, and where possible to coincide with drainage ditches, road cuttings etc. to enable ease of sampling. If this was not possible a large pit was dug to a depth of at least one metre. Not all soils were sampled as some are of small areal extent.

Soils were sampled horizon by horizon rather than at set intervals of measurement (i.e. every 10cm). This method of sampling was considered adequate to provide the main chemical characteristics and trends of individual soils, thus allowing the comparison of different soil profile classes. Sample material was taken over as much of the horizon as practicable, and at least from the top, middle and base of each horizon. The knife and/or spade used to collect the sample was cleaned between each horizon to minimize contamination of samples.

Soil samples were placed in sealed plastic bags to be taken to the laboratory where they were air dried and ground to less than 2mm before further processing. Samples of peat were also air dried then wrapped in aluminium foil.

4.1.2 Chemical analyses

pH

METHOD.

Soil profile classes were tested for pH, horizon by horizon to a depth of one metre. Samples had pH measured in distilled water, 1M KCl and 0.01M $CaCl_2$.

PROCEDURE.

A ten gram sample of air dried soil ground to less than 2mm was mixed vigorously with the appropriate liquid (distilled water, 1M KCl or 0.01M $CaCl_2$), and left to stand overnight. Samples were stirred again and left for a minimum of thirty minutes before measurements were taken. The pH meter was adjusted with buffers of pH 4 and pH 7 at the beginning of each batch, and tested at various intervals. When pH was measured the glass electrode was placed in the sediment, the reference electrode in the

supernatent, and both electrodes were rinsed with distilled water between each measurement.
Several samples were replicated, and every fifth sample measured twice to ensure reproducibility of results.

TOTAL CARBON AND C%

METHOD.

Combustion in a Leco induction furnace was used to determine total carbon content of samples. The method involves rapidly heating a soil and catalyst mixture in a stream of oxygen to high temperatures (> 1400°C), converting all forms of carbon to carbon dioxide. This means that results will be influenced by the presence of calcium carbonate, charcoal and undecomposed material as well as humified organic carbon. Carbon dioxide produced by combustion is purified then absorbed by ascarite within a collection bulb. The amount of carbon dioxide is measured gravimetrically from the increase in weight of the ascarite absorption bulb after each sample.

PROCEDURE.

A sample of dry soil ground to less than 1mm was accurately weighed into a ceramic crucible and a scoop of each of the iron, copper and tin chips which act as catalysts added. The following guidelines were used to assess the amount of soil to use:

topsoils	100 - 400 mg
subsoils	500 - 1000 mg.

Several replicates of one soil sample were run through to stabilise the ascarite bulb before any readings were taken. Individual samples were combusted in the Leco furnace for four minutes before removing the bulb for wieghing. At least two replicates of each sample were processed, and if these did not agree closely a third replicate was done. In all cases the third replicate was very close in value to one of the first two. Average values are reported.

$$C\% = \frac{\text{weight gain of bulb} \times 0.2729 \times 100}{\text{weight of sample}}$$

Glucose was used as a standard to check the efficiency of the process. If the recovery of carbon from glucose was below 100% the C% values were adjusted accordingly.

Organic matter is calculated by multiplying the amount of organic carbon by the factor 1.7 (Blakemore and Miller 1968).

TOTAL N

METHOD.

An acid digest method was used and the nitrogen content in the solutions compared to known standards using the Auto-Analyser.

PROCEDURE.

Samples of 0.5 g air dried soil ground to less than 2mm were weighed into digest tubes. Two replicates of each sample were processed, as well as at least one blank (no soil), with each batch. To each tube was added 4 ml of concentrated acid. The soil-acid mixture was then heated in a digest block to a temperature of 350°C for five hours and left to cool overnight. The solution in the digest tubes was made up to 50 ml with double distilled water, mixed thoroughly, then filtered. Filtered solutions were processed by the Auto-Analyser, and the peaks they produced compared to a standard curve drawn from the peaks formed by known standard solutions.

For 0.5 grams of soil made up to 50 ml,

$$N\% = \frac{\text{ugN/ml}}{100}$$

PHOSPHOROUS

METHODS.

Three fractions of phosphorous were measured:

(1) Inorganic, non fixed P;
This fraction is soluble in a solution of 0.5M H_2SO_4.

(2) Organic P;
This fraction is determined by the increase in 0.5M H_2SO_4 soluble P after samples have been ignited at high temperatures. This converts organic P to inorganic phosphate. Calcium acetate is added to the samples prior to ignition to prevent any loss of P during the process.

(3) Total P;
The sample is digested in concentrated acid and the resulting liquid measured for P content.

PROCEDURE.

(1) INORGANIC NON FIXED P.

A 0.50 gram sample of air dry soil ground to less than 2mm was put into a 250 ml shaking jar along with 100 ml of 0.5M sulphuric acid (H_2SO_4). A blank is also processed with each batch. The solutions are shaken overnight at 20°C, then filtered. The filtered solution is put through the Auto-Analyser and the resultant peaks compared to a standard curve prepared from peaks of standard solutions of known P concentration. Results are converted from g/ml to mg/100g by the following equation.

ugP/ml x 20 = 0.5M H2SO4 soluble P (mg/100g)

ORGANIC P.

A 0.50 gram sample of air dry soil ground to less than 2mm was put into a silica crucible, wet with 20% calcium acetate, then dried at low temperature. Samples (plus a blank with each batch) were heated at 550°C for an hour and left to cool overnight. Procedure is then as for the inorganic non-fixed P, with samples being shaken overnight with 100 ml of 0.5M sulphuric acid, filtered, and the amount of P measured by Auto-Analyser. Organic phosphorous is determined by the following equation;

Ignited 0.5M H_2SO_4 soluble P - 0.5M H_2SO_4 sol P = organic P.
(all values of P are in mg/100g)

TOTAL P.
Samples of 0.5 g air dried soil ground to less than 2mm were weighed into digest tubes. Two replicates of each sample were processed, as well as at least one blank (no soil), with each batch. To each tube was added 4 ml of concentrated acid. The soil-acid mixture was then heated in a digest block to a temperature of 350°C for five hours and left to cool overnight. The solution in the digest tubes was then made up to 50 ml with double distilled water, mixed thoroughly, then filtered. Filtered solutions were processed by the Auto-Analyser. Peaks formed by the solutions were compared to a standard curve drawn from peaks formed by standard solutions of known P concentration. The value of total P in mg/100g is calculated as follows;

Total P in mg/100g = ugP/ml x 10.

4.2.0 Soil pH

The pH of a soil depends on the composition of the parent material and the amount of leaching it has undergone. Leaching occurs in humid climates when precipitation exceeds evapotranspiration, and gradually removes soluble salts, readily soluble soil minerals and bases from the soil. As leaching and soil profile development take place the topsoil becomes slightly to moderately acid, although the subsoil may remain neutral or alkaline. In time the entire profile becomes acidic (Miller 1965, Bohn 1979).

Acidity may be produced by plant residues or organic wastes may decompose to produce organic acids thus acidifying the surface soil. Organic acids are particularly important in forest soils (Bohn 1979).

The pH of soil has both spatial and temporal variation. In soil profiles a difference of more than one pH unit can occur in the space of a few millimetres, and in some parent materials highly acid conditions can arise. An example of this would be the exposure of sulphides (commonly found in mine tailings) to the air as they oxidise to produce sulphuric acid. One soil within the study area, formed in tailings composed of estuarine and lacustrine sediments, is reported as containing sulphides. As well as long term changes in pH due to weathering and leaching of the parent material, pH also fluctuates seasonally in many soils (Miller 1968, Bohn 1979).

Within the soil most reactions take place on colloid surfaces with adsorption, desorption, solution and precipitation all occuring to keep the surfaces in equilibrium with the pH of the environment. Effective hydrogen ion concentrations near soil particle surfaces appear to be 100 to 1 000 times greater than in bulk solution. However the apparent pH of a soil as taken with a pH metre reflects hydrogen ion activities in the bulk solution surrounding the electrodes rather than that around the soil particle. To obtain more valid pH measurements it is recommended that the calomel reference eletrode is placed in the supernatent solution, and the glass electrode in the settled suspension. This recommended method of pH measurement was the one adopted in the current study (Bohn 1979, New Zealand Soil Bureau Record 80 1987).

Water, KCl and $CaCl_2$ are all used as suspension mediums for the measurement of soil pH (New Zealand Soil Bureau Record 80 1987). When using salt solutions as a suspension medium measured pH can be lowered by as much as 0.5 - 1.5 units compared to pH in distilled water. This is because the cations of the salt solutions can displace acidic hydrogen and aluminium cations from soil particle surfaces thus lowering the measured pH. Thus the greater the difference between measured pH in distilled water and a salt solution such as 1M KCl, the fewer bases included in the exchangable cations of the soil particles (i.e. a greater propertion of sites are occupied by acidic cations such as H^+ and Al^{3+}) (Miller 1968, Bohn 1979, New Zealand

Soil Bureau Record 80 1987).

It is considered that measured pH in KCl may approach the pH of the ion atmosphere of the original soil, and that 0.01 CaCl2 is similar in electrolyte composition to soil solutions found at optimum moisture conditions (New Zealand Soil Bureau Record 80 1987).

YELLOW BROWN SANDS.
Measured pH ranges from moderately acid to slightly alkaline in most yellow-brown sands, depending on age and leaching. Most are weakly weathered, with near neutral pH levels, especially in subsoils (Daly 1977).

RECENT SOILS.
Measured pH in recent soils ranges from the extremely acid surface horizons of saline gley recent soils to extremely alkaline for subsoils associated with calcium carbonate. However most recent soils are moderately acid to near neutral reflecting the lack of leaching due to their youth (Searle 1985).

4.2.2 Measured pH of soil samples.

YELLOW-BROWN SANDS
The measured pH of the yellow-brown sands in the study area ranges from 4.8 to 6.8, with most of the readings being slightly to moderately acid (5.3-6.5) (see Table IV). In all cases the surface horizons are more acidic than the subsoils, probably reflecting the presence of organic acids in the relatively organic rich A horizons. The most acidic sample is the A horizon of Manihera sand, this horizon also has a particularly high organic matter content.

All subsoils except that of Parera sand show a difference of more than 1.5 pH units between the pH in distilled water and the pH in 1M KCl at some depth. This difference shows the presence of acidic cations on the exchanger, indicating that leaching of bases has occurred. The highest difference measured was 2.0 pH units in the subsoil of Kahutara sand. As these soils are found on the oldest dune sand within the study area (dune set one), it is to be expected that they would be the most leached. Parera sand soils show a difference of less than one pH unit. They are formed on the most recent dune line, and due to their youth very little leaching will have occurred.

GLEY RECENT SOILS

The slowly accumulating gley recent soils are slightly to moderately acid (5.3-6.5), the surface horizons being the most acidic, pH increasing with depth.

The subsoil of Ahikouka silty clay loam has a difference of more than 1.5 pH units between pH measured in distilled water and 1M KCl, indicating the leaching of bases and their replacement on the exchanger by acidic cations.

Although Ahikouka silty clay loam on sand has a difference of more than 1.5 pH units in the B horizon, below this subsoils have a difference of less than one pH unit. A possible explanation for this phenomenon could be due to bases leached out of the silty clay loam textured A, AB and B horizons into the sandy subsoils. Because of their coarse texture, the sandy subsoils would have a smaller CEC than the above horizons and thus require fewer bases to have a relatively high base saturation.

The pH measurements of the slowly accumulating gley recent soils are generally slightly acid to near neutral (6.0-7.0). This shows the lack of leaching, due to their youthfulness. Te Hopai clay and Lake shore sand subsoils are both saturated with water for long periods of time, and this is reflected in their slightly alkaline pH. The pH of Onoke silty clay loam subsoil measured in distilled water is 4.5. This is attributed to the presence of sulphur, which oxidises to sulphuiric acid, and a high salt content.

Table VI Laboratory Analyses

Soil name	Horizon	Depth (cm)	pH in H2O	pH in KCl	pH in CaCl2	Organic matter C%	Organic matter N%	Organic matter C/N	Phosphorous (mg/100g) P(I)	P(O)	P(Ig)	P(T)
SOILS OF THE SAND DUNES												
Kahutara sand	A	0-10	5.7	4.3	4.4	1.85	0.15	12	35	41	76	46
	Bw	10-36	6.0	4.8	5.2	0.42	0.04	11	49	25	74	39
	BC	36-63	6.7	4.7	4.5	0.14	-	-	-	-	-	-
	C	63 on	6.6	4.6	3.8	-	-	-	-	-	-	-
Wairio sand	A	0-20	5.7	4.6	5.0	3.49	0.35	10	58	48	106	64
	Bw	20-32	6.0	4.5	4.5	0.35	0.06	6	66	28	94	45
	C	32 on	6.0	4.4	5.0	-	-	-	-	-	-	-
Wairo mottled sand	A	0-30	5.7	4.2	4.5	2.05	0.17	12	40	50	90	51
	Bg	30-60	6.0	4.3	4.7	0.20	0.02	10	40	26	66	26
	Cg	60-90	6.2	4.3	4.9	-	-	-	-	-	-	-
	Cr	90 on	6.2	4.5	5.2	-	-	-	-	-	-	-
Mangatete sand	A	0-35	5.9	4.6	4.9	2.49	0.20	13	42	54	96	60
	Bg	35-50	6.2	4.5	5.0	0.29	0.03	10	27	38	65	25
	Cr	50 on	6.2	4.4	5.0	-	-	-	-	-	-	-
Manihera sand	A	0-20	4.8	3.6	3.8	4.40	0.46	10	83	66	149	105
	C	20 on	5.8	4.3	4.7	-	0.02	-	53	26	79	30
Manihera mottled sand	A	0-7	5.6	4.3	4.6	4.00	0.42	10	50	41	91	63
	Cu	7-64	6.0	4.1	4.5	0.26	0.02	13	44	14	58	26
	Cr	64 on	6.2	4.6	5.3	-	-	-	-	-	-	-
Kumenga sand - dune phase	A	0-14	5.8	4.4	5.0	0.62	0.06	10	56	29	85	-
	Cr1	14-81	6.8	5.1	5.9	-	0.03	-	51	18	69	30
	Cr2	81 on	6.6	5.2	5.8	-	-	-	-	-	-	-
Parora sand	A	0-4	6.3	5.2	-	0.60	0.04	15	60	23	83	31
	C	4 on	6.5	5.6	-	-	0.03	5	60	12	72	25
SOILS OF THE SLOWLY ACCUMULATING FLOODPLAIN												
Ahikouka silty clay loam	A	0-20	5.9	4.7	5.3	1.53	0.17	9	25	52	77	34
	AB	20-48	6.3	4.8	5.6	0.63	0.08	8	24	49	73	25
	Bgc	48-68	6.3	4.7	5.5	0.24	0.03	8	40	27	67	28
	Cr	68 on	6.4	4.5	5.3	0.13	-	-	-	-	-	-
Ahikouka silty clay loam on sand	A	0-31	5.2	4.2	4.6	1.89	0.16	12	25	64	89	36
	AB	31-48	5.4	4.2	4.6	0.86	0.08	11	30	38	68	75
	Bgc	48-61	5.9	4.1	4.8	0.25	0.03	8	39	25	64	26
	2Cr	61-82	6.2	5.5	5.5	-	-	-	-	-	-	-
	3Cr	82 on	6.5	5.9	5.8	-	-	-	-	-	-	-
SOILS OF THE RAPIDLY ACCUMULATING FLOODPLAIN												
Pukeo clay loam	A	0-19	5.7	4.7	5.2	2.41	0.24	10	51	61	112	68
	AC	19-36	6.1	4.5	5.2	0.51	0.05	10	62	24	86	43
	Cr	36 on	6.9	4.5	5.9	0.24	-	-	-	-	-	-
Pukeo clay loam on sand	A	0-17	6.3	5.2	5.8	2.59	0.25	10	76	40	116	64
	Cr	17-72	6.4	5.0	5.8	0.50	0.06	8	62	18	80	40
	2Cr	72-100	7.0	5.5	6.2	0.29	-	-	-	-	-	-
Te Hopai clay	Cr1	0-49	5.9	4.5	5.0	1.20	0.15	8	72	32	104	44
	Cr2	49-58	6.4	5.0	5.6	0.40	0.05	8	55	20	75	34
	Cr3	58 on	7.1	5.7	6.1	0.19	-	-	-	-	-	-
Lake shore sand	Cr	0-100	7.5	6.8	-	0.16	-	-	52	23	76	27

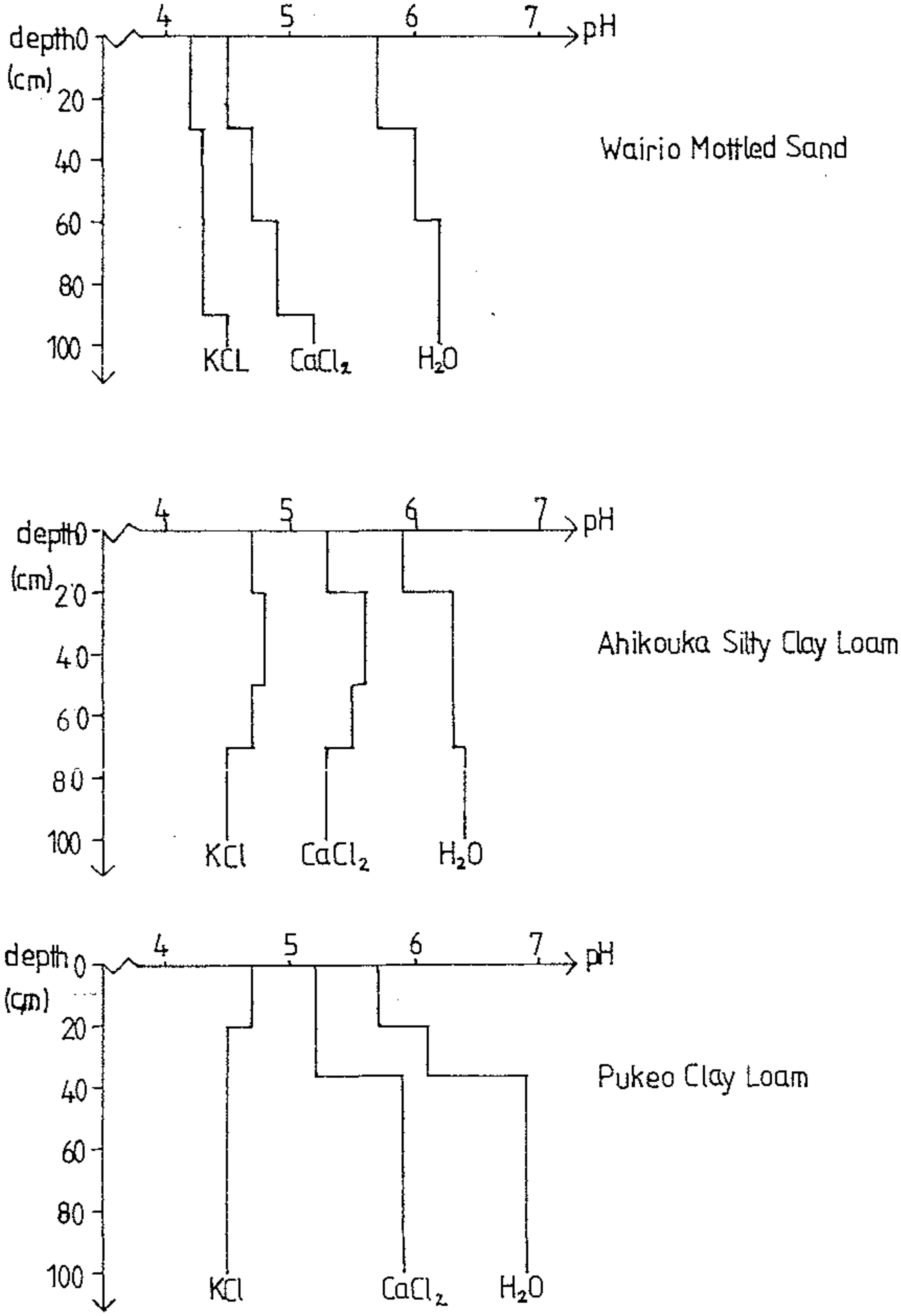


Figure 25.
The variation in measured pH in distilled water, 1M KCl and 0.01M $CaCl_2$ with depth.

4.3.0 Soil organic matter.

4.3.1 Literature review.

The processes involved in the formation of soil organic matter are;

(a) Formation
Creation of organic material by growing plants.

(b) Decomposition
Soil fauna and microorganisms modify organic residues of plant and animal origin.

(c) Complex formation
Inorganic soil constituents (clays) form complexes with organic matter, the two materials becoming intimately associated.

Because of the vital roles of plants, soil fauna and soil microorganisms in the formation of soil organic matter, its build up and turnover are dependent on environmental factors such as light, temperature, moisture and aeration. Changes in theses environmental factors can favour or inhibit the activities of the above species, thus changing the intensity of and or all of the above processes. Favourable conditions are required for the effective production and processing of organic matter. In turn the amount of organic matter in a soil has a strong effect on such properties as soil structure, aeration, CEC, pH and the availability of nutrients (Blakemore and Miller 1968).

To help characterise the organic matter of soils the amounts of organic carbon and total nitrogen are commonly determined. Organic matter itself is calculated by multiplying the amount of organic carbon by the factor of 1.7 (Cowie et al 1967, Blakemore and Miller 1968). The determination of carbon and nitrogen allows the derivation of the carbon:nitrogen ratio (C/N), which is very useful as its value indicates the extent of decomposition of soil organic matter. Litter material characteristically has very high values, organic rich topsoils moderately high values and subsoils low values (Blakemore and Miller 1968).

ORGANIC CARBON

Topsoils usually have much higher organic carbon values than their associated subsoils. This is because of the return of plant material to the surface and the subsequent high level of soil organisms present in the surface layers involved in the breakdown of this material (Blakemore and Miller 1968).

YELLOW-BROWN SANDS.

The yellow-brown sands tend to have low organic carbon values as they are often too young to have produced much plant material (Blakemore 1962). A chronosequence of sand dunes on the Manawatu coast showed and initial rapid gain in carbon content during the first 500 to 1 000 years, followed by a slower rate of gain. However even after 10 000 years carbon was not considered to have reached a steady state Carbon initially accumulated in the topsoil but with increasing time it also started to accumulate in the subsoil due to eluviation, pedoturbation or *in situ* decomposition of plant roots (Syers *et al* 1970).

RECENT SOILS.

Organic carbon levels tend to be low in alluvial soils, especially if they are young and there is little organic carbon build-up or translocation in these soils. Alluvial soils are usually fertile and thus capable of producing large amounts of organic material, however their youth often means that organic carbon has not had the opportunity to accumulate. Frequent deposition of sediment on floodplains may interrupt plant growth as vegetation is buried by silts. Subsoils especially may reflect the organic carbon content of the parent material (Blakemore and Miller 1968, Searle 1985).

In gley recent soils the high water table saturates the soil forming anaerobic conditions. Under these conditions decomposition of organic matter is slowed considerably allowing the build-up of organic carbon, some of which would be lost as CO_2 during aerobic decomposition. It follows that in soils of the same age, poorly drained soils tend to have a greater build up of organic carbon than well drained soils (Blakemore and Miller 1968).

NITROGEN

Patterns follow those of organic carbon as both are produced by the decomposition of plant material. As with organic carbon, levels of nitrogen are greatest in the topsois, and decrease with depth in the subsoil, and initial rapid gains in the first 500 to 1 000 years are followed by a slower rate of gain. With increasing time nitrogen will also accumulate in the subsoil due to eluviation, pedoturbation or *in situ* decompostion of plant roots (Blakemore and Miller 1968).

YELLOW-BROWN SANDS AND RECENT SOILS.

Yellow-brown sands and alluvial soils tend to have low nitrogen values, wheras the gley soils have high values due to the presence of organic matter under anaerobic conditions (Blakemore and Miller 1968, Syer *et al* 1970).

CARBON TO NITROGEN RATIOS.

Carbon to nitrogen ratios indicate the extent of decomposition of organic matter and high values are found where decomposition is slowed by climatic or soil conditions impeding microbiological activity, or where the litter is naturally slow to decompose (Blakemore and Miller 1968, Cowie *et al* 1967).

Under aerobic conditions, as organic matter decomposes carbon is lost as carbon-dioxide, with the residual nitrogen being built into the relatively stable constituents of humus. Thus with increasing decomposition C/N ratios decrease. Ratios also normally decrease with increasing depth because of the influence of dead and decomposing plant material on topsoil values. A value of 10 to 12 indicates a stable well decomposed type of organic matter and in cultivated soils the ratio is generally stable at about 10 (Cowie et al 1967, Blakemore and Miller 1968).

YELLOW-BROWN SANDS.

Cowie et al (1967) found medium to high C/N ratios in the yellow-brwon sands of the Manawatu. Syers et al (1970) reported that as the rate of gain of organic carbon was greater than that of nitrogen in the dune soils, the C/N ratios increased with increasing age.

RECENT SOILS.

In recent soils most values are low to medium indicating the ready decomposition of organic matter of relatively fertile soils. Gley recent soils have high values, especially in surface horizons, due to the retardation of decomposition. Subsoil horizons may have low values due to the fixation of nitrogen into inorganic compounds (Searle 1985).

4.3.2 C%, N% and C/N ratios of soil samples.

ORGANIC CARBON

YELLOW-BROWN SANDS

The carbon content of the yellow-brown sands of the study area ranges from low and medium values (2-4 and 4-10) in topsoils, to very low values in all the subsoils. These ratings follow the usual trend of carbon enriched topsoils with values decreasing with depth.

In previous studies dune soils have had carbon contents which increase with age, no such pattern seems evident in this study. The youngest dune soil, Parera sand, has the lowest C% value (0.06), but the next youngest dune soil, Manihera sand, has the highest value (4.40). The oldest dune soil, Kahutara sand, which could be expected to have the most carbon has even less than Wairio sand which is younger (values of 1.85 and 3.49 respectively).

Manihera sand has an exceptionally high C% value in relation to the other soils. The discovery of Maori cooking stones near the sample site implies that the soil may have been cultivated by the Maori. Leach (1981) suggests that the area is marginal for the growth of kumera, and that if kumara was grown at all in the district it would have to have been in well drained soils which warmed more rapidly than the wet low lying clays. If the particular site that was sampled had been cultivated by the Maori it allows the following interpretation. It it is assumed that if Manihera sand (dune set 3) had been sampled elsewhere, values would have been intermediate between those of Parera sand (dune set 4), and Wairio sand (dune set 2). C% would increase with age, with the exception of Kahutara sand soils (dune set 1), whose low carbon content could be attributed to its excessive drainage and the subsequent long periods of moisture stress suffered by the vegetation.

Another interpretation of C% values obtained gives weight to the importance of environmental factors in the production of plant materials and thus on the accumulation of soil organic carbon. In particular the effect of available soil moisture, and the tendency for dune soils to dry out is considered. Within the study area, the height of the dunes decreases with decreasing age. Dune sets 1,2 and 3 reach up to 40, 20 and 12 metres respectively, whilst those of dune set 4 reach a maximum of only three to four metres. All the dune soils are excessively drained, but droughtiness is most marked on the higher dunes where soils are high above the water table and dry out quickly in the summer. On the lower dunes deep rooting plant species have access to water for longer periods of time, through much of the spring and summer, although they do dry out eventually. The availability of water allows a prolonged period for the growth of vegetation on the younger dunes, which in turn leads to a greater accumulation of organic matter and therefore carbon. The increase in C% with decreasing age reflects the availability of water for plant growth, C% reaching a maximum in Manihera sand (dune set 3). The low value for organic carbon in Parera sand (dune set 4) can be attributed to its youth, as it has not yet had sufficient time to accumulate an appreciable amount of organic matter.

GLEY RECENT SOILS

Soils of the slowly accumulating floodplain, Ahikouka silty clay loam and Ahikouka silty clay loam on sand both have very low values for C%, and very low to low N% levels. These soils are older than those on the rapidly accumulating floodplain, and could be expected to have accumulated more organic carbon and nitrogen, but the reverse is true.

Pukeo clay loam and Pukeo clay loam on sand, on the rapidly accumulating floodplain, have low C% and N% ratings in their topsoils, and very low values in their subsoils. The area is naturally very wet, even with artificial drainage the water table may be within one metre of the surface for long periods during the year. The very wet conditions in winter would inhibit plant growth, but the availability of water during the spring and summer months would be beneficial to organic matter production.
Te Hopai clay loam soils have very low values throughout their profiles, but as they have only been drained for less than ten years this is not surprising. Lake shore sands also have very low levels.

C/N RATIOS.

YELLOW-BROWN SANDS

The yellow-brown sands have ratios of 10 to 15 in surface horizons, the highest value of 15 coming from the immature Parera sand soils of dune set 4. Generally ratios decrease with depth. Less well drained soils tend to have higher values, reflecting the retardation of decomposition by wet conditions.

GLEY RECENT SOILS

These soils typically have very low to low ratios which decrease with increasing depth. This shows the rapid and well decomposed nature of the organic matter in spite of wet winter conditions.

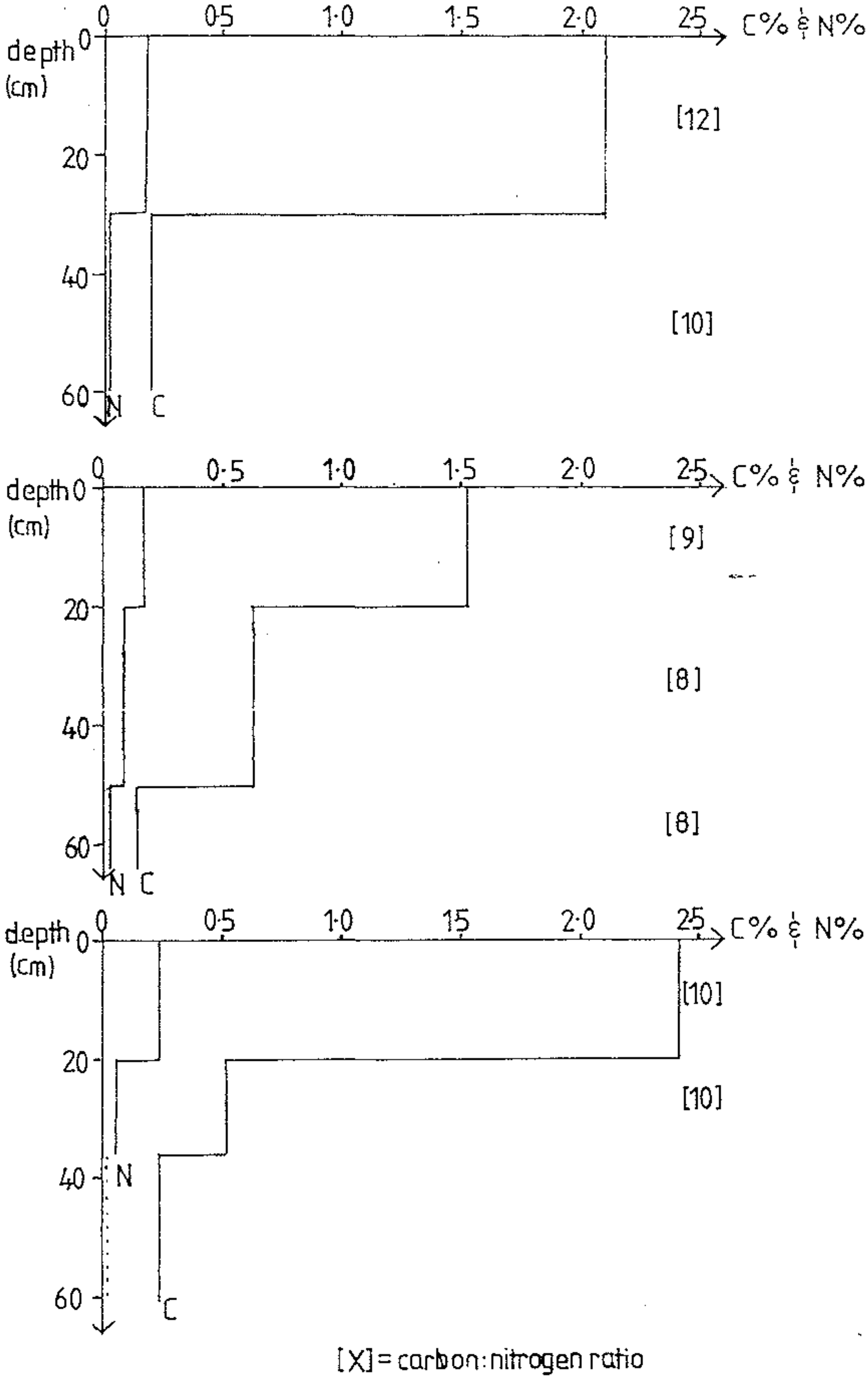


Figure 26.
The variation of C%, N% and the carbon:nitrogen ratio with depth for three soil profiles.

4.4.0 Phosphorous.

4.4.1 Literature review.

Phosphorous is the only element in soil organic matter which must by supplied by the parent material of unfertilised soils due to negligligle atmospheric returns. Thus total phosphorous levels of soils are broadly related to the phosphorous content of the parent material (Metson 1956, Walker and Adams 1958, Walker and Syers 1976).

Total phosphorous (P_T) in soils is made up of two main forms, inorganic phosphorous (P_I) and organic phosphorous (P_O). The inorganic fraction can be further subdivided into the non-occluded phosphorous (Pa) which is extracted by 0.5M H_2SO_4, and occluded phosphorous (Pf) which is not 0.5M H_2SO_4 extractable (Saunders 1968, Walker and Syers 1976).

$$P_T = Pa + Pf + Po$$

In soils with a pH of less than 6.5 inorganic phosphorous is generally combined with iron and aluminium, calcium bound inorganic phosphate the dominant form in soils with a pH greater than 6.5 (Saunders 1968, Syers and Walker 1969B, Walker and Syers 1976). Non-occluded phosphorous includes the Ca-bound phosphorous such as in the mineral apatite, and the phosphate ions at the surfaces of iron and aluminium oxides and oxyhydroxides. Occluded phosphorous consists of the phosphate ions bound within the lattices of compounds, and incorporated in coatings and concretions of oxides and hydrous oxides of aluminium and iron (Walker and Syers 1976).

The rapid removal of phosphorous from solution by soil is known as phosphate retention, and at pH of less than 6.5 is due to compounds of iron and aluminium. Phosphate fixations is a slow process which occurs after retention, having the result of making phosphorous unavailable to plants (Saunders 1968).

In soils developed in windblown sand in the Manawatu it was found that P_T declined during soil development. Weathering slowly releases phosphorous from apatite, it is then either converted to Po by plants and soil microorgansms, lost by leaching in freely drained soils, or retained by aluminium and iron compounds to form secondary forms of inorganic phosphorous (Syers and Walker 1969A and 1969B).

With the onset of soil formation organic phosphorous increases rapidly at first, the rate of accumulstion decreasing after a period of 500 to 1 000 years. Organic phosphorous may form between 3-63% of the total. The increase of organic phosphorous occurs initially in the surface horizon, amounts decreasing down the profile, however with increasing time the organic phosphorous content of subsoils also increases due to the eluviation of or the *in situ* decompostion of organic matter (Syers and Walker 1969A, Syers *et al* 1970). Coarse texture may limit the build up of organic matter and thus organic phosphorous.

The weakly weathered nature of the sands means that phosporous retention (and thus fixation) is low, making the loss of phosphorous by leaching more likely (Syers and Walker 1969A, Syers *et al* 1070).

When the rate of release of phosphorous by apatite is less than losses of phosphorous by leaching and/or conversion to unavailable forms, organic phophorous may mineralise rapidly. Eventually with continuing weathering and leaching only a small amount of organic phosphorous and unavailable inorganic phosphorous will remain (Syer and Walker 1969A, Syers *et al* 1970, Walker and Syers 1976).

YELLOW-BROWN SANDS

The phosphorous levels in yellow-brown sands are usually quite high due to their low level of weathering. Phosphorous retention is low in well drained soils but may rise in soils with impeded drainage which contain mottling and concretions. Compared to freely draining soils, poorly drained soils have a lower total phosphorous, much of which is made up of inorganic phosphorous. Total and organic phosphorous both have a more marked decrease with depth in poorly drained soils (Walker and Suyers 1976, Daly 1977).

RECENT SOILS

Most recent soils have medium values for total phosphorous, any high values are due to organic phosphorous in the topsoil. Generally most of the inorganic phosphorous is extractable in 0.5M H_2SO_4. This indicates that the soils are weakly weathered and that most inorganic phosphorous is primary. Phosphorous retention values are generally low.

In gley soils soluble forms of phosphorous are transported to the gley horizon where they can be continually moved by lateral drainage. In time the total phosphorous of the soil will be depleted (Saunders 1968, McGaveston 1978).

4.4.2 Phosphorous levels of soil samples.

In this study the parent materials are aeolian sand and alluvium derived mainly from greywacke. Apatite, a calcium phosphate mineral provides almost all the phosphorous present in greywacke, a South Island sample having a value of 650 parts per million. Alluvial soils can contain appreciable amounts of organic matter and thus organic phophorous. In all soils total phosphorous and organic phosphorous are highest in the A horizon due to the accumulation of organic matter, and decreases with depth down the profile (Walker and Adams 1958, Walker and Syers 1976).

Interpretation of the phosphorous fractions is complex and is made more difficult with the different soils having horizons of varying thicknesses. To aid in the interpretation of the chemical analyses, results have been calculated as percentages of phosphorous to depths of 20, 40 and 60 centimetres (see Table V).

As can be seen from Table V, the values of total phosphorous as determined from the concentrated acid extractable fraction, and that determined by ignition of the soil sample followed by extraction with 0.5M H_2SO_4 do not agree. As the ignited sample measures organic phosphorous and non occluded inorganic phosphorous, it would be expected that total phosphorous which also measures occluded phosphorous would equal or slightly exceed the ignited sample values, however this is not the case. The most likely explanation is that calibration was not correct, or that results supplied by the Auto Analyser were incorrerctly calculated with respect for the dilution factor. However N% results determined from the same solutions appear to be correct, therefore the concentrated acid must have failed to extract all the phosphorous in the sample.

Because of this anomaly, in the following discussion, the total phosphorous referred to is the total gained by the addition of organic phosphorous and non-occluded inorganic phosphorous (P(Ig) in Table VI) as this total is influenced directly by changes in the two fractions. Therefore the total phosphorous P(T) in Table VII is equivalent to P(Ig) rather than P(T) of Table VI.

YELLOW-BROWN SANDS.

The yellow-brown sands of the study area have total phosphorus levels which are generally high in topsoils and medium in subsoils (Table X). This is made up of medium to high values of inorganic phosphorous throughout the soils, and high to very high organic phosphorous levels in topsoils, falling to low to medium in subsoils. These values follow the trend of those found in a chronosequence of dunes in the Manawatu where total phosphorous levels were generally high, due to the weakly weathered and leached nature of the soils.

There is a trend with increasing age for the amount of inorganic phosophorous to decrease as expected (Table VII), but the trend for organic phosphorous is not so obvious. The amount of organic phosphorous in

Table VIIPhosphorours Values Adjusted for Depth

Soil name	Depth (cm)	Phosphorous (g/100 P(I)	P(O)	P(T)	Proportion of P(O):P(T)
SOILS OF THE SAND DUNES.					
Kahutara sand	0-20	0.77	0.74	1.51	49%
	20-40	0.98	0.50	1.48	34%
Wairio sand	0-20	1.16	0.96	2.12	45%
	20-30	0.67	0.28	0.95	29%
Wairio mottled sand	0-20	0.80	1.00	1.80	56%
	20-40	0.80	0.76	1.56	49%
	40-60	0.80	0.52	1.32	39%
Mangatete sand	0-20	0.84	1.08	1.92	56%
	20-40	0.77	1.00	1.77	56%
	40-60	0.27	0.38	0.65	57%
Manihera sand	0-20	1.66	1.32	2.98	44%
	20-40	1.06	0.52	1.58	33%
	40-60	1.06	0.52	1.58	33%
Manihera mottled sand	0-20	0.92	0.47	1.39	34%
	20-40	0.44	0.14	0.58	24%
	40-60	0.88	0.28	1.16	24%
Kumenga sand - dune phase	0-20	1.09	0.51	1.60	32%
	20-40	1.02	0.24	1.44	17%
	40-60	1.02	0.24	1.44	17%
Parera sand	0-20	1.20	0.28	1.48	19%
	20-40	1.20	0.24	1.44	17%
	40-60	1.20	0.24	1.44	17%
SOILS OF THE SLOWLY ACCUMULATING FLOODPLAIN					
Ahikouka silty clay loam	0-20	0.50	1.28	1.78	72%
	20-40	0.60	0.76	1.36	56%
	40-60	0.31	0.62	0.93	67%
Ahikouka silty clay loam on	0-20	0.50	1.04	1.54	68%
sand	20-40	0.49	1.01	1.50	67%
	40-60	0.67	0.77	1.44	53%
SOILS OF THE RAPIDLY ACCUMULATING FLOODPLAIN					
	0-20	1.03	1.18	2.21	53%
Pukeo clay loam	20-40	1.24	0.48	1.72	28%
	40-60	1.24	0.48	1.72	28%
	0-20	1.49	0.73	2.21	33%
Pukeo clay loam on sand	20-40	1.23	0.36	1.60	23%
	40-60	1.23	0.36	1.60	23%
	0-20	1.44	0.64	2.08	31%
Te Hopai clay	20-40	1.44	0.64	2.08	31%
	40-60	1.25	0.51	1.76	29%
	0-20	1.04	0.48	1.52	32%
Lake shore sand	20-40	1.04	0.48	1.52	32%
	40-60	1.04	0.48	1.52	32%

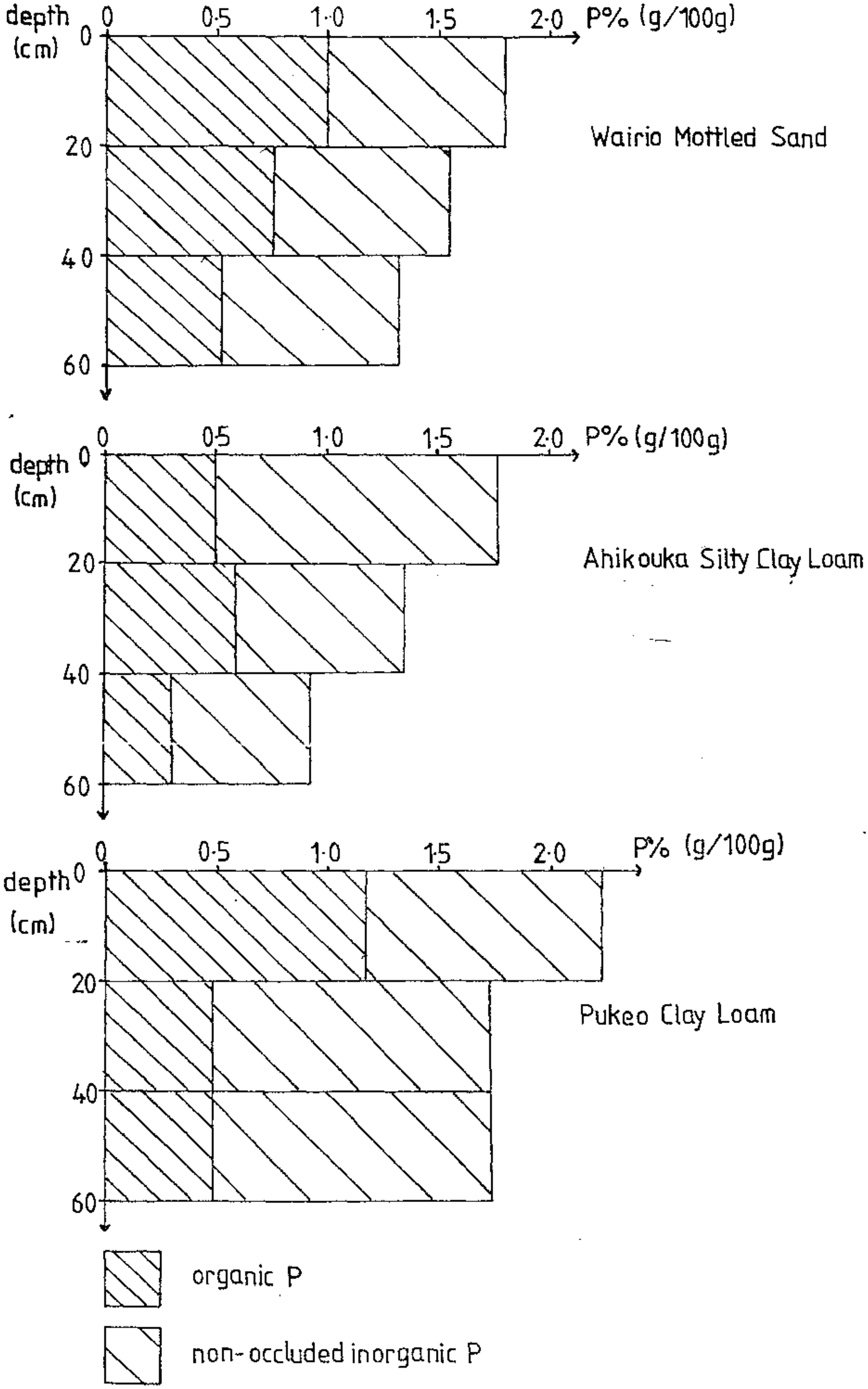


Figure 27
The variation in organic and non-occluded inorganic P% with depth for three representative soil profiles.

Manihera sand is very high, and is probably related to the very high amounts of organic matter in this soil. It is interesting to note from Table VII that even though the level of organic phophorous is very high, so is that of inorganic phosphorous.

The only yellow-brown sand soils which have a greater percentage of organic than inorganic phosphorous are the Wairio mottled sand and Mangatete sand soils (dune set 2), although Kahutara sand (dune set 1) is close to having equal amounts. The youngest soil, Parera sand, has only 17-19% of its total phosphorous composed of organic phosphorous. This is the lowest proportion of any of the dune soils as would be expected.

With increasingly poor drainage, both organic and inorganic phosphorous levels decrease in soils of dune set 3, but increase in soils of dune set 2.

GLEY RECENT SOILS

In the slowly accumulating soils the values for inorganic phosphorous are medium to high, and those for organic phosphorous are high to very high to a depth of 60 cm. Both total and organic phosphorous levels decrease with increasing depth. These soils have a high proportion of organic phosphorous, with it supplying 53-72% of the total.

The rapidly accumulating gley recent soils have mostly high total phosphorous values in subsoils as well as topsoils. The lake shore sand has a medium rating. Levels of organic phophorous are medium to high in surface horizons, but are only low to medium in subsoils. Both total and organic phosphorous values decrease with depth (Table Y), those of inorganic phosphorous being remarkably constant.

Only Pukeo clay loam has a proportion of organic phosphorous which exceeds 50% of the total - this soil also has a relatively high content of organic matter.

CHAPTER FIVE: SUMMARY AND DISCUSSION.

The Holocene marine transgression invaded the lower Wairarapa Valley forming an extensive estuary by its culmination *circa* 6 500 years ago. The beach ridges, dunes, spits and cliffs which formed around the maximum extent of the estuary have been noted by several workers and together form the highest Holocene shoreline. The estuary opened to Palliser Bay through an area known as The Narrows. Uplifted marine benches with stranded shorelines at the base of wave cut cliffs are found on either side of The Narrows, showing that the valley was also estuarine during the Last Interglacial.

Sedimentation by the two principle rivers, the Ruamahanga and the Tauherenikau, gradually filled in the estuary. Earthquake movement is recorded by uplifted beach ridges at Turakirae Head (at the southernmost point of the Rimutaka Range) but it is uncertain if the study area would have been affected by these events due to the intervening West Wairarapa Fault. It is not agreed whether or not the study area experienced any uplift during the 1855 earthquake, but if it did it would have been very minor.

A large event or events leading to the extremely rapid deposition of silty sediments in the Kumenga and Birchwood area killed living shellfish by burying them deeply enough to prevent their escape. Organic material overlying blue-grey estuarine sand and immediately below the silty sediment was dated at c. 3 500 years BP in the Kumenga area and at c. 3 600 years BP in the Oporua floodway. Thus estuarine conditions persisted until about this time. A gravelly deposit just south of Kahutara is associated with the sediments which overlie the estuarine sands. A large catastrophic event is inferred from the coarse nature of these deposits. All other material deposited by the Ruamahanga River in the area is generally finer than coarse sand.

A delta formed in the area south of Kuahutara where the Ruamahanga River discharged into the estuary, the gravels being incorporated into the growing delta plain. The delta continued to prograde, the Ruamahanga River mouth apparently moving gradually southwards with time. Delta progradation ceased when the Ruamahanga started to discharge at a much more southerly point.

A new delta started to form at the new entry point and the change in position coincided with a change in the size of material deposited. The much finer sediment accumulating on the new delta plain suggests that by this time the environment of deposition was lacustrine rather than estuarine. Closure of the mouth of the estuary mouth was effected by the Onoke gravel bar which probably grew by the accumulation of material transported by longshore drift, assisted by uplift. A possible time for the final closure of the estuary mouth, and the change in course of the Ruamahanga River could be 3 100 years ago, the estimated date of an earthquake which stranded one of the beach ridges at Turakirae Head.

The estuary would have been converted into a blind estuary once fully enclosed by the Onoke gravel bar. With the removal of the tidal currents sedimentation would have been rapid in the region of the Narrows, causing the separation of Lakes Onoke and Wairarapa.

The Ruamahanga delta has formed in a lacustrine environment as shown by its lobate shape and the formation of the mid-ground bar at the mouth of the river.

The Wairarapa Catchment Board diverted the Ruamahanga River in 1968, normal flows no longer entering Lake Wairarapa. This was done as part of a flood protection scheme for the lower Wairarapa Valley. Lake levels are kept purposefully low by the diversion of the Ruamahanga River and a barrage at the southern end of the lake to prevent backflow from the lower river. The lake can then be used to accommodate flow from the Ruamahanga River when it is in flood (water entering the lake via the Oporua floodway). As sediment is no longer being supplied to the lake in any appreciable amounts the delta is no longer prograding.

In the study area dune lines have formed over the cliff cut by the highest Holocene shoreline, and along the outer margin of each delta. These dunes have been formed from the accumulation of sand blown onshore from the estuary or lake margin by the common north-westerly winds.

Soils formed in the dune sands have allowed the recognition of four separate dune sets on the basis of the strength of soil profile development. Dune set one is the oldest, outermost dune line, and dune set four the youngest. Soil profiles show an increase in the number and depth of horizons with increasing age.

Soil profiles have been described and compared to soils developed in dune sands in the Manawatu. These comparisons and known time limits have allowed the ages of the dune soils in the study area to be estimated;

soils of dune set 1	6 000 years
soils of dune set 2	3 000 years
soils of dune set 3	500 years
soils of dune set 4	60 years

These ages are only approximate, and may vary to either side of that estimated. The soils of the two older dune sets especially could be up to 500 years younger or older than the date given.

Dateable material was found in a number of places within the study area, and obtaining more dates would help to provide the exact timing of some of the events described above. Investigating the area between Kahutara Road and the Ruamahanga River, and also the Kumenga Peninsula could provide valuable and interesting information about the area.

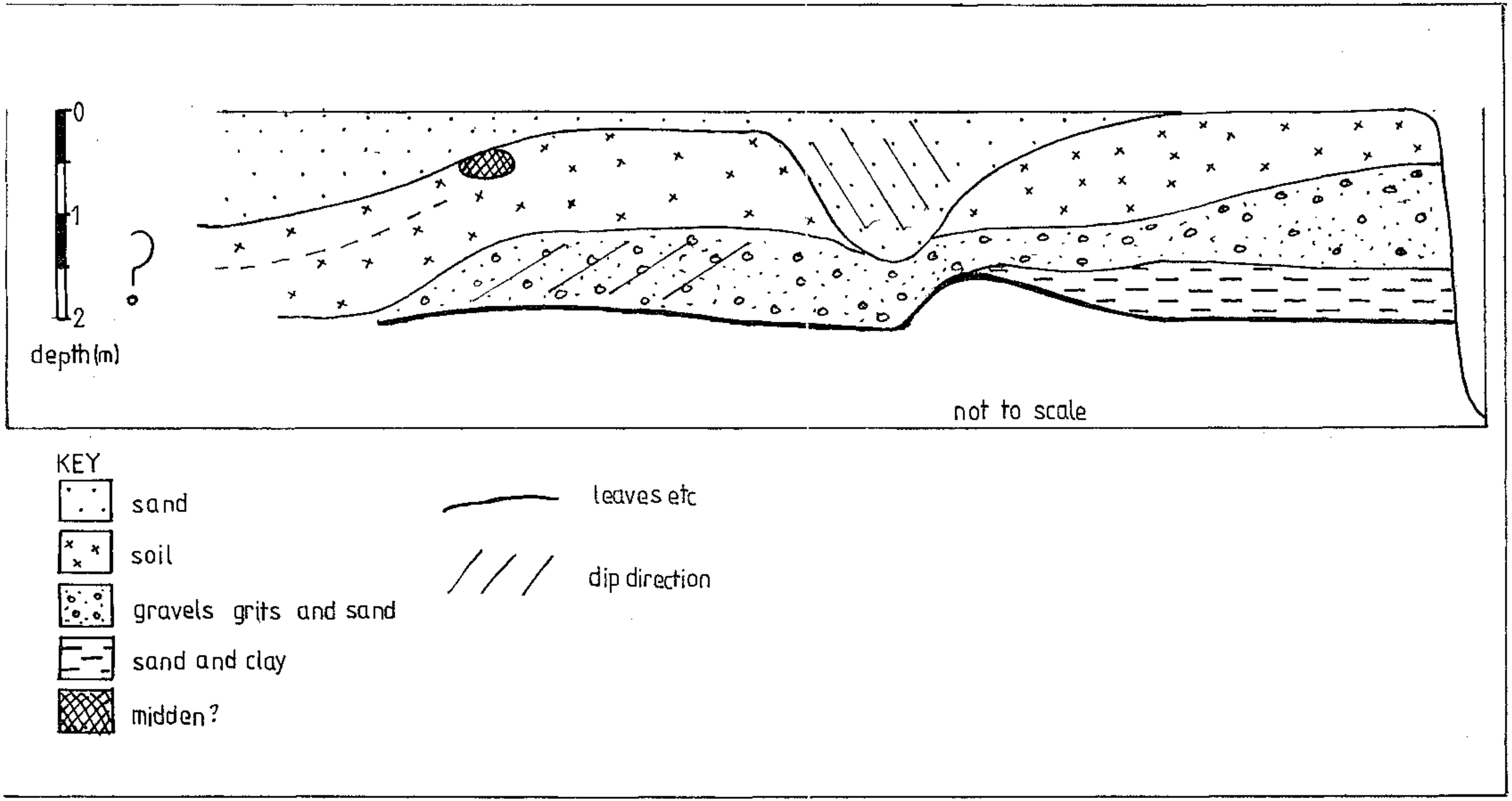


Figure 18 CROSS SECTION THROUGH THE OPORUA FLOODWAY.

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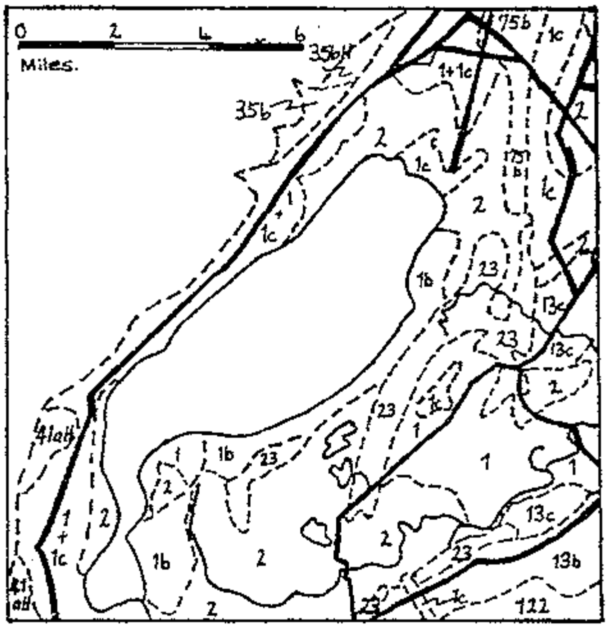
Appendix One: Summary of sediment size classification.

	US Standard sieve mesh	*Millimeters*		*Phi (φ) units*	*Wentworth size class*
GRAVEL	*Use wire squares*	4096		-12	
		1024		-10	boulder
		256	256	- 8	
		64	64	- 6	cobble
		16		- 4	pebble
	5	4	4	- 2	
	6	3.36		- 1.75	
	7	2.83		- 1.5	granule
	8	2.38		- 1.25	
	10	2.00	2	- 1.0	
SAND	12	1.68		- 0.75	
	14	1.41		- 0.5	very coarse sand
	16	1.19		- 0.25	
	18	1.00	1	0.0	
	20	0.84		0.25	
	25	0.71		0.5	coarse sand
	30	0.59		0.75	
	35	0.50	1/2	1.0	
	40	0.42		1.25	
	45	0.35		1.5	medium sand
	50	0.30		1.75	
	60	0.25	1/4	2.0	
	70	0.210		2.25	
	80	0.177		2.5	fine sand
	100	0.149		2.75	
	120	0.125	1/8	3.0	
	140	0.105		3.25	
	170	0.088		3.5	very fine sand
	200	0.074		3.75	
	230	0.0625	1/16	4.0	
SILT	270	0.053		4.25	
	325	0.044		4.5	coarse silt
		0.037		4.75	
		0.031	1/32	5.0	
		0.0156	1/64	6.0	medium silt
	Use	0.0078	1/128	7.0	fine silt
	pipette	0.0039	1/256	8.0	very fine silt
CLAY	*or*	0.0020		9.0	
	hydro-	0.00098		10.0	clay
	meter	0.00049		11.0	
		0.00024		12.0	
		0.00012		13.0	
		0.00006		14.0	

Appendix Two: Soils previously mapped in the study area.

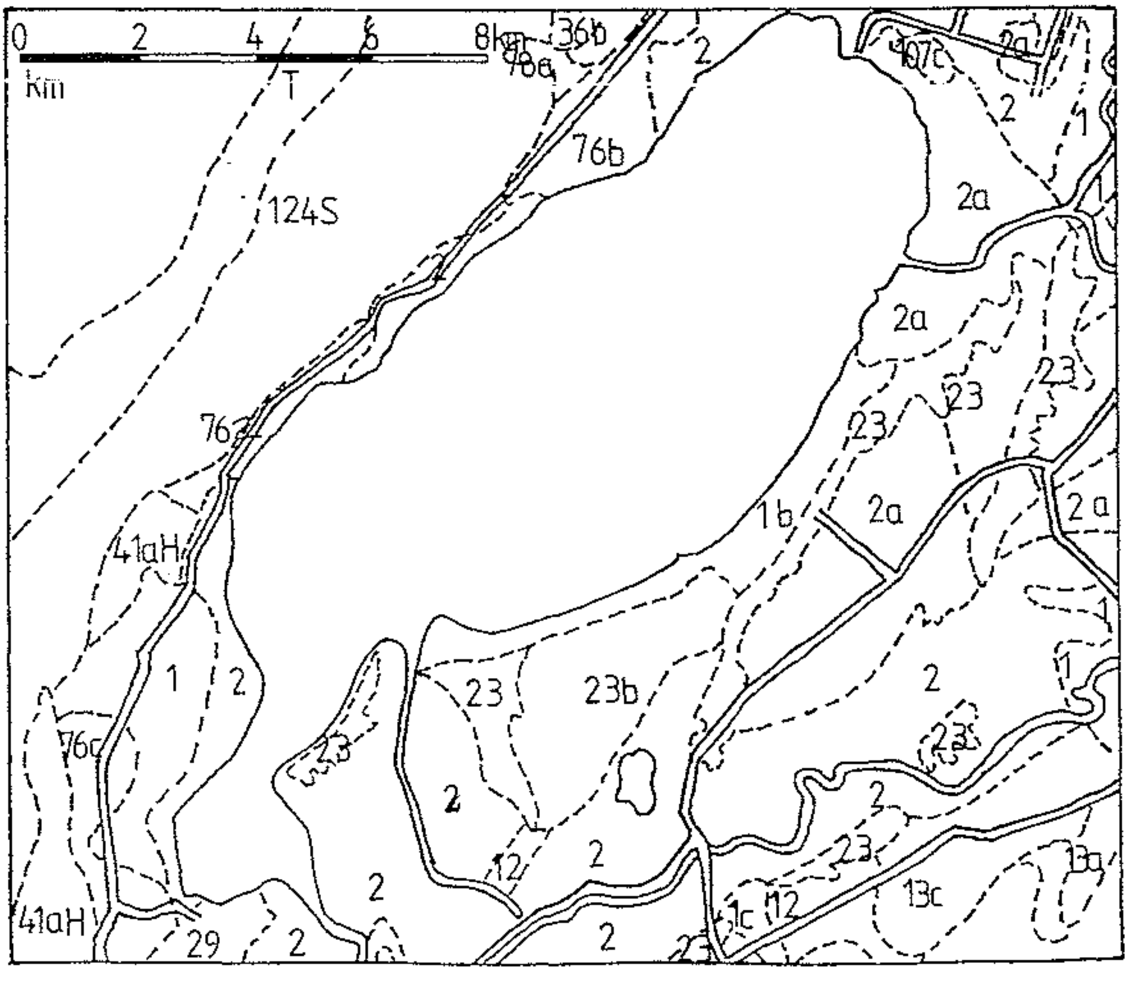


Map 1.

from N.Z. Soil Bureau, 1945.
Scale 1: 253, 440.

Map 2.

from Heine, 1975.
Scale 1: 126, 720.



APPENDIX 3: SOIL PROFILE DESCRIPTIONS.

BRIEF PROFILE DESCRIPTIONS - FROM N.Z. SOIL BUREAU 1954.

Manawatu loam, sandy loam, silt loam and clay loam (1).

6-12 in.	light-brown or dark-grey loam, etc.,
on,	mellow brown-grey, or yellow loam and clay loam.

Esk sand (1b).

1-6 in.	greyish-brown or black sand,
on,	grey-brown sand.

Tukituki sandy loam, stony gravel, etc. (1c).

	Shallow brown sandy loams,
on,	stony gravel.

Kairanga silt loam and clay loam (2).

6-12 in.	grey silt loam,
on,	clay loam mottled grey and brown.

Patea sand (23).

6-18 in.	black sand,
on,	pale-grey sand.

BRIEF PROFILE DESCRIPTIONS - FROM HEINE 1975.

SOILS OF THE FLOOD PLAINS AND SWAMPS.

Ruamahanga sand (1b).

Rapidly accumulating recent soil from alluvium.

8-15cm	greyish-brown sand
over,	grey loose sand, gravel and stones.

Ahikouka silt loam (2).

Slowly accumulating gley recent soil from alluvium.

15-20cm	dark brownish grey silt loam, on
20-30cm	greyish yellow heavy silt loam, yellow mottles
over,	grey silty alluvium.

Pukeo clay loam (2a).

Rapidly accumulating gley recent soil from alluvium.

8-15cm	brownish grey clay loam, on
12-15cm	yellowish grey clay loam,
over,	silt and clay sediments.

Onoke silty clay (3).

Rapidly accumulating saline gley recent soil.

3-15cm	grey and greyish brown silyt clay,
on,	bluish grey silty clay.

SOILS OF THE SAND DUNES.

Manihera sand (23).

Moderately leached central yellow-brown sand.

15-23cm	brownish black sand
on,	yellowish brown loose sand.

Kumenga mottled sand (23b).

Moderately leached gleyed yellow-brown sand.

25cm	black sand
on,	grey sand; yellowish mottles to 70-80cm.

SOILS OF THE RIVER TERRACES AND FANS.

Martinborough loam (12).

Moderately leached weakly gleyed central yellow-grey earth.

20cm	greyish brown powdery loam, on
30-60cm	brownish yellow to pale yellow firm fine sandy loam; faint orange and grey mottles.
over,	gravels and stones below 50cm.

PROFILE DESCRIPTIONS - FROM COWIE AND MONEY 1965

Ruamahanga Series

Recent soils with a gravelly or stony sand, sand, or loamy sand texture, occur mring frequently on flooded flats bordering rivers and along old courses and overflow channels.

1-3 in.	very dark brown (10YR 2/2) stony loamy sand; very friable to loose; weakly developed medium granular structure; many roots; distinct boundary,
on,	sandy gravels.

Ahikouka Series

Poorly drained gley recent soils, subject to occasional flooding and accumulation of fresh alluvium. Soils have friable nutty topsoils over firm clay or heavy silt loams with weak blocky structure and many distinct reddish mottles.

12 in.	dark greyish brown to very dark greyish brown (10Yr 4/2-3/2) silt loam; friable; strongly developed fine nutty structure; many roots; few distinct fine reddish mottles increasing to many in low 3 in.; distinct boundary,
16 in. +	grey to olive grey (5Y 5/1-4/2) clay loam; many distinct medium reddish brown mottles; firm; weakly developed medium blocky structure; slightly sticky; slightly plastic; some roots.

APPENDIX FOUR

SOIL TAXONOMIC UNIT DESCRIPTIONS

Soil profile class A

Reference\classification

Soil name:	Onoke silty clay
County:	Featherston
Classification:	
NZ Genetic;	Rapidly accumulating saline gleyed recent soil.
Taxonomy;	Aquic Ustifluvent (fine silty over skeletal, mixed, mesic).
References:	
Original set;	Mercer loam etc, 2c.
NZSB Rec. 40;	Onoke silty clay. Gleyed soils, developed in materials dredged out of the new channel for the Ruamahanga River.
This survey;	Kept consistent with NZSB Rec. 40, i.e. gleyed, mottled soils developed in dredge tailings.
Symbol of mapping unit:	On

Environmental factors

Geographical location:	Along the lower reaches of the Ruamahanga River channel.
Parent material:	Dredge tailings dumped during construction of the Ruamahanga River diversion channel.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On dune-like features formed by the dumping of tailings, also material pumped into swamps and hollows.
Slope class:	Easy rolling - moderately steep to steep.
Range of slope:	Less than 5° on crests, up to 30° on sides.
Vegetation:	
Original;	None, previously river bed.
Present;	Pasture.
Range of elevation:	3-6m.
Land use:	Grazing for sheep.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°C.
Soil temperature regime:	Mesic.
Soil drainage class:	Moderately well drained
Soil moisture class:	Imperfectly drained.
Permeability:	Low.
Flooding:	
Frequency;	On topographic high and would therefore not flood.
Duration;	NA
Erosion:	
Type;	Slip.
severity;	Slight.

Morphological and chemical features

Characteristic profile features

A thin topsoil with very weakly developed structure over massive silts\sands\gravels. The subsoils are dominated by low chroma colours and ochreous mottles.

Typifying profile #1

Ah	5cm	Brownish black (10YR2\3) silty-fine sandy loam; sticky and plastic; weakly developed nut and single grain structure; abundant roots; straight distinct boundary.
Cr 5	on	Olive brown (2.5Y4\3) silty clay loam with bright brown-yellowish brown (7.5YR-10YR5\8) and light grey-grey (10Y7\7-6\1) mottles; sticky and plastic; massive; common to no roots.

Range of profile features (# of observations - 7)

Ah horizons 5 - 15cm thick.
Cr of varying thickness, from greater than 1m to approximately 40cm, sat on
2Cr of sand and gravels.

Similar soils and distinguishing features

SPC-I — Distinguished by position in landscape and by texture, (does not sit on sand and gravels).

SPC-W — Found close to the lake shore and the profile is sandy throughout.

Chemical data — Not assessed.

Potentials and limitations to use.

Not assessed as area of Onoke silty clay is very small within the study area.

Land use capability. — Not assessed.

Soil profile class B

Reference\classification

Soil name:	Wairio sand
County:	Featherston
Classification:	
NZ Genetic;	Moderately leached yellow brown sand.
Taxonomy;	Typic Ustipsamment (sandy, mixed, mesic).
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Manihera sand Sand soils on hummocky dunes east of Lake Wairarapa that have brownish black topsoils on yellowish-brown sand.
This survey;	Name 'Manihera sand' kept for sand soils with an A/C profile, and 'Wairio sand' used specifically for the well drained soils of dune set 2 which have A/B/C profile development.
Symbols of mapping units:	Wo1

Environmental factors

Geographical distribution:	On aeolian dunes (dune set 2) which extend NE-SW from Mangatete Stream, across the ends of Whareroto and Judds roads, to immediately east of the Boggy Pond and Mathew's Lagoon wildlife reserves.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On crests and shoulders of the dunes.
Slope class:	Easy rolling - moderately steep.
Range of slope:	5 to 23°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Mainly pasture with small area of pine trees.
Range of elevation:	8-20m.
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic.
Soil drainage class:	Excessively drained.
Soil moisture class:	Ustic.
Permeability:	Very rapid.
Flooding:	
Frequency;	On upper slopes on dunes, therefore would not flood.
Duration;	NA
Erosion:	
Type;	Slip, not generally prone to wind erosion under pasture.
Severity:	Slight.

Morphological and Chemical features

Characteristic profile features

A dark, friable topsoil, over a B horizon with weakly developed structure, on a massive pale subsoil. There is no mottling.

Typifying profile (#7)

Ah	18cm	Brownish black (10YR 2/2) friable sandy loam; weakly to moderately developed nut and block structure; sticky and plastic; abundant roots; indistinct boundary.
Bw	12cm	Dark brown (10YR 3/4, rubbed) friable to loose sand; very weakly developed coarse nut and block structure; slightly sticky and plastic; many roots; indistinct boundary.
Cu	on	Dull yellowish brown (10YR 4/3) loose sand; non sticky and non plastic; common to few roots.

Range of profile features (# of observations - 9)

Depths of the A and B horizons vary between 14-28cm, and 10-40cm respectively.
AB horizons may be present, showing the interfingering of brownish black topsoil with the brownish B horizon.
B horizon dominated by hues of 10YR and 2.5Y. Colours range from dark brown - brown to yellowish - Olive brown.
Mottles are not permitted in this soil, if mottles are present below 45cm the soil belongs to soil profile class C.

Similar soils and distinguishing features

SPC-V:	Found on dune set 4. Soils lack a structured B horizon, having only A/C profiles.
SPC-X:	Found on crests and shoulders of dune set 3. Soils are less well developed and lack structured B horizons, having only A/C profiles.
SPC-M:	Found on crests and shoulders of dune set 1. Soils are well developed with a BCw horizon in addition to the Bw horizon present in both SPC-B and SPC-M.

Chemical data

pH	Moderately - slightly acid
C%	Low
N%	Medium - low
C/N ratio	Low
inorganic P	Very high
organic P	Medium

Limitations and potentials for use

Pastoral;	Limitations of insufficient moisture.
Cropping;	Soils of hilly land with very severe limitations to crop production - unsuitable.
Horticultural;	Soils of hilly land with very severe soil limitations to horticultural use - not suitable.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of hilly land with moderate limitations to urban use (limitations are mainly of slope and erosion).
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pastoral;	5A
Cropping;	4
Horticultural;	4
Forestry;	2B
Urban;	4
Value for food production:	2

Soil profile class C

Reference/classification

Soil name:	Wairio mottled sand
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Kumenga mottled sand: Sandy soils in depressions between dunes, having black topsoils overlying grey sand with yellowish brown mottles.
This survey;	'Kumenga mottled sand' retained for mottled sand soils with A/C profiles, 'Wairio mottled sand' introduced to denote soils of dune set 2 with mottling deeper than 45cm.
Classification:	
NZ Genetic;	Moderately leached gleyed yellow brown sand
US Taxonomy;	Typic Ustipsamment (sandy, mixed, mesic)
Symbols of mapping unit:	Wo2

Environmental factors

Geographical distribution:	On aeolian dunes (set 2) which extend NE-SW from Mangatete Stream, along the western ends of Whareroto and Judds roads, to immediately east of the Boggy Pond and Mathew's Lagoon wildlife reserves.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On backslopes and moderately well drained toeslopes of dunes.
Slope class:	Easy rolling - rolling.
Range of slope:	5 - 15°
Vegetation:	
Original:	Podocarp and dicotylous forest.
Present:	Mainly pasture with some pinetrees.
Range of elevation:	4 - 10m
Land use:	Grazing for sheep and cattle, few trees.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8 - 17°.
Soil temperature regime:	Mesic
Soil drainage class:	moderately well drained
Soil moisture class:	ustic
Permeability:	very rapid
Flooding:	
Frequency;	On the sides of the dunes therefore not likely to flood.
Duration;	NA
Erosion:	
Type;	Slip, - not prone to wind erosion under pasture.
Severity;	slight

Morphological and Chemical features

Characteristic profile features

These have a deep, dark friable topsoil and a weakly developed Bw horizon. The subsoils have ochreous mottles from approximately 45cm depth. Low chroma mottles may be found at greater depths.

Typifying profile (#27)

Ahp	30cm	Brownish black (10YR 3/2) friable sandy clay loam; weakly to moderately developed medium nut structure; sticky and plastic; abundant roots; diffuse boundary.
Bw	15cm	Dull yellowish brown - dark brown (10YR 4/3-3/3) friable to loose sandy loam; weakly developed coarse block structure; slightly sticky and plastic; common roots; indistinct boundary.
Cg	20cm	Olive brown (2.5Y 4/3) loose loamy sand; with common small to medium ochreous mottles; massive; non sticky and non plastic; few roots; indistinct boundary.
Cr	on	Olive grey (2.5GY 6/1) and yellowish brown (10YR 5/8) mottled loose sand; single grain; non sticky and non plastic; no roots.

Range of profile features (# of observations - 3)

A and B horizons range in thickness from 24 - 30cm and 15 - 30cm respectively.
The A and B horizons may have a few faint fine mottles.
Low chroma mottles may be found deep in the subsoil. (>65cm)

Similar soils and distinguishing features

SPC-Q:	Found on dune set 3. These soils lack a B horizon having only A/C profiles.

Chemical data

pH	Moderately - slightly acid
C%	Low
N%	Low
C/N ratio	Medium
inorganic P	High to very high
organic P	Medium

Limitations and potentials for use

Pastoral;	Limitations of insufficient moisture and to a lesser extent, nutrients.
Cropping;	Limitations of subsoil pans and drainage impediments.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of flat and rolling land with moderate soil limitations to urban use.
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pastoral;	2A
Cropping;	2B
Horticultural;	3A
Forestry;	2B
Urban;	2
Value for food production;	2

Soil profile class D

Reference\classification

Soil name:	Mangatete sand
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Kumenga mottled sand: Sandy soils in depressions between dunes, which have black topsoils overlying grey sand with yellowish brown mottles.
This survey;	'Kumenga mottled sand' retained for soils with A/C profiles, mottled to below the topsoil. Name Mangatete sand introduced to describe soils of dune set 2 which have A/B/C profiles, and which are mottled to within 45cm of the surface. (often to just below the topsoil).
Classification:	
NZ Genetic;	Moderately leached gleyed yellow brown sand.
Taxonomy;	Mollic psammaquent (sandy, mixed, mesic).
Symbols of mapping units:	Mt

Environmental factors

Geographical distribution:	On aeolian dunes (set 2), which extend NE-SW from Mangatete Stream, along the western ends of Whareroto and Judds roads, to immediately east of the Boggy Pond and Mathew's Lagoon wildlife reserves.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On toeslopes of dunes and in swales.
Slope class:	Gently undulating - easy rolling.
Range of slope:	Generally less than 3°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Pasture and rushes.
Range of elevation:	2 - 6m
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Imperfectly to poorly drained.
Soil moisture class:	Aquic
Permeability:	Very rapid.
Flooding:	
Frequency;	Probably flooded 2 - 3 times per decade before stopbanks (designed for 50 year return period flood) were built.
Duration;	Floodwaters would infiltrate rapidly through sand, lingering for only a few days.
Erosion:	
Type;	none
Severity;	NA

Morphological and chemical features

Characteristic profile features

Have a deep, dark, friable topsoil with fine ochreous mottles. The B horizon is mottled and has weakly developed structure. The subsoil has abundant low chroma mottles.

Typifying profile

Apg	21cm	Brownish black (10YR 2/3) friable loamy sand; with few fine indistinct brown (10YR 4/6) mottles; moderately developed coarse nut and block structure; sticky and plastic; abundant roots; distinct irregular boundary.
Bg	34cm	Dark greyish yellow - yellowish brown (2.5Y 5/2-5/3) loamy sand; with dark reddish brown (5YR 3/6) mottles; weakly developed coarse block structure; slightly sticky and plastic; many fine roots, indistinct boundary.
Cr	on	Olive grey (2.5GY 5/1-6/1) loamy sand to sand with reddish brown (5 YR 4/6) mottles; single grain structure; non sticky and non plastic; few roots. (water table ≈ 120cm in October)

Range of profile features (# of observations - 3)

Generally brownish black topsoil ranges from 15 - 40cm thick, and may have few fine ochreous mottles.
B horizon 10 - 35cm thick, and is dominated by 10YR - 5YR hues (dark reddish brown to brown) with few low chroma mottles,i.e. <2%.
C horizons become increasingly gleyed with depth, the abundance of ochreous mottles decreasing and 2.5GY hues dominating, i.e. olive grey.
Usually no/few concretions.

Similar soils and distinguishing features

SPC-W:	Mottled to the surface and sandy throughout as SPC-D: but is found in association with dune set 3. Also lack B horizons having A/C profiles.
SPC-C:	Not mottled to the surface. Mottles (especially low chroma mottles) are characteristically found at depths greater than 45cm.

Chemical data

pH	Moderately to slightly acid
C%	Low
N%	Low
C/N ratio	Medium
inorganic P	High to very high
organic P	Medium to high

Limitations and potentials for use

Pasture;	Limitations of drainage and nutrients.
Cropping;	Limitations of drainage.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of flat and rolling land with moderate soil limitations to urban use.
Value for food production;	Soils of high potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	1C
Horticultural;	3A
Forestry;	2B
Urban;	2
Value for food production;	1B

Soil profile class E

Reference\classification

Soil name:	Te Hopai sandy clay
County:	Featherston
Reference:	
Original set;	NA
NZSB Rec. 40;	Lagoon beds at time of survey, since drained.
This survey;	Defined as gleyed soils in recently drained or ephemeral lagoon beds, textures containing sand in the subsoil.
Classification:	
NZ Genetic;	Rapidly accumulating gley recent soil.
Taxonomy;	Typic Haplaquent (fine loamy, mixed, mesic).
Symbols of mapping units:	Th2

Environmental factors

Geographical distribution:	Small localised areas in between Lake Wairarapa and boundaries formed by the old Ruamahanga River channel, East-West Access Road and dune set 2.
Parent material:	Alluvial silts and clays over lacustrine sand, often with freshwater mussel shells.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	In localised hollows of the rapidly accumulating flood plain of the lower Ruamahanga River, ie between the lake and dune set 2. These were the site of shallow lagoons most of which have been drained within the last 5 to 10 years.
Slope class:	Flat - gently undulating.
Range of slope:	0 - 2°
Vegetation:	
Original;	Previously underwater.
Present;	Bullrushes, rushes, sedge, grass, willows.
Range of elevation:	< 1m.
Land use:	Rough grazing for cattle.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Very poorly drained.
Soil moisture class:	Aquic.
Permeability:	Poor.
Flooding:	
Frequency;	Low lying land which due to slow permeability will pond water during winter months. Before stopbanks were built (designed for 50 year return period flood) probably flooded annually, possibly permanently underwater.
Duration;	Once flooded, water is removed form these hollows by slow infiltration and evaporation; therefore water likely to remain for several weeks to months depending on the volume of water.
Erosion:	
Type;	nil
Severity;	NA

Morphological and Chemical features

Characteristic profile features

No friable dark topsoil, though partially decomposed organic material (litter), may lie on the surface. Profiles are massive, textures containing sand by approximately 30cm, (ie sandy clay loam). Soils are gleyed, with low chroma colours and mottles present to the surface.

Typifying profile (#214)

Cg	10cm	Yellowish grey - greyish yellow (2.5Y 6/1-6/2); very firm silty clay loam to silty clay with small prominent bright brown (7.5YR 5/8) mottles; sticky and plastic; massive to coarse blocky structure; many roots; distinctive boundary.
Cr	on	Olive grey (10YR 6/2) massive loamy sand to sandy clay loam with dull yellowish brown to yellowish brown (10YR 5/4-5/6) large distinct mottles and about 1% small bright reddish brown (5YR 5/8) mottles; non sticky and non plastic; common to no roots.

Range of profile features (# of observations -5)

Litter may be present, up to a depth of 4cm.
May contain freshwater mussel shells, these are generally found at depths of 30-40cm, sitting over sand and buried by silty alluvium.
Lower layers may be very gleyed to produce dark greenish grey/blue grey sands and muds which are free of any ochreous mottles.
Litter layers (L/F/H), are common at the surface.

Similar soils and distinguishing features

SPC-J	Dominated by silt and clay textures with minor or no sand at depths less than 80-90cm.
SPC-W	Have topsoils, and textures are sandy throughout.
SPC-I	Have topsoils, also subsoil textures dominated by silt and clay throughout.

Chemical data

pH	Strongly to moderately acid.

Limitations and potentials for use

Pasture;	Limitations of subsoil pans and drainage.
Cropping;	Limitations of wet low-lying land that is not easily drained.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of low actual or potential value for food production.

Land use ratings

Pasture;	3B
Cropping;	3B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	3

Soil profile class G

Reference\Classification

Soil name:	Te Pare stony silty clay loam.
County:	Featherston
Reference:	
Original set;	Tukituki sandy loam, stony gravel etc. 1c.
NZSB Rec. 40;	Ahikouka silt loam. (shown on map as Pukeo clay loam) On the NZSB Record 40 map, the soils Pukeo clay loam and Ahikouka silt loam were transposed, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed. Ahikouka silt loam is described as having dark brownish topsoil, on a greyish yellow mottled silt loam horizon, on grey silty alluvium.
This survey;	Describes a shallow stony soil found in association with Ahikouka soils on the slowly accumulating floodplain.
Classification:	
NZ Genetic;	Slowly accumulating gleyed recent soil from alluvium.
Taxonomy;	Humic Haplaquept (?, mixed, mesic)
Symbols of mapping units:	Tp

Environmental Factors

Geographical distribution:	Area around the intersection of Judds road and Kahutara road.
Parent material:	Alluvium, silty clay loam over grits and gravels.
Parent rock:	Greywacke/argillite and minor Tertiary sediments.
Physiographic position:	On the slowly accumulating floodplain of the lower Ruamahanga River, between dune sets 1 and 2.
Slope class:	Flat to gently undulating.
Range of slope:	Less than 5°, generally less than 2° .
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Improved ryegrass, clover pasture.
Range of elevation:	3 - 6m.
Land use:	Dairying.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Moderately well drained.
Soil moisture class:	Poorly drained.
Permeability:	Moderate permeability.
Flooding:	
Frequency;	Before stopbanks built (designed for 50 year return period flood) probably flooded 3 - 5 times a decade.
Duration;	Few days to a week.
Erosion:	
Type;	Nil.
Severity;	NA

Morphological and Chemical Features

Characteristic profile features

A shallow stony soil (greater than 5% stones), with only the topsoil not stony. The soil is stony to very stony (5-60% stones) from less than 20cm depth, although sometimes on sand by approximately 45cm.

Typifying profile (#58)

Ap 10cm	Brownish black (10YR 3/2) friable fine sandy clay loam; moderately developed medium nut structure; sticky and plastic; abundant roots; wavy distinct boundary.
Cu on	Very stony (clast supported); with brown and dull yellowish brown (10YR 4/6 and 5/3) mottled sand between clasts; non sticky and non plastic; common to few roots.

Range of profile features (# of observations - 3)

The percentage of stones throughout the profile may vary, the important criteria being at least 35% stones which reach to within 20cm of the surface, and to a depth of 40-45cm. Subsoils may contain no, few or abundant stones. Stones often rest over coarse sand containing grit and/or concretions. Other lenses and/or layers of stones may be found at depth.

Similar soils and distinguishing features

SPC-L — Resemble Te Pare stony silty clay loam soils except;
- they are stony to very stony (ie greater than 5% stones) at depths greater than 20cm and less than 45cm. (May sit on sand)
- have less than 5% stones (ie 'with stones') in the top 20cm.

Chemical data — Not assessed.

Limitations and potentials for use

Pastoral;	Limitations of drainage and nutrients.
Cropping;	Limitations of shallow and stony profiles, with serious moisture deficiency.
Horticulture;	Limitations of excessive drainage and stoniness.
Forestry;	Limitations of shallow and stony profiles and insufficient moisture.
Urban;	Soils of flat and rolling land with minimal to slight soil limitations to urban use.
Value for food production:	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	3A
Horticultural;	3B
Forestry;	3B
Urban;	1
Value for food production;	2

Soil profile class H

<u>Reference\Classification</u>

Soil name:	Kumenga mottled sand on silty clay.
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Pukeo clay loam. (Ahikouka silt loam on map) Pukeo clay loam and Ahikouka silt loam were transposed on the map accompanying NZSB Record 40, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed. Pukeo clay loam soils have brownish grey clay loam topsoils overlying yellowish grey clay loam, on silt and clay sediments.
This survey;	Recognises a soil previously undescribed. Dull yellowish brown topsoil and gleyed sands overlie gleyed silty alluvium, commonly having peat or peaty loam at the base of the sands.
Classification:	
NZ Genetic;	Moderately leached gleyed central yellow-brown sand.
Taxonomy;	Aeric Haplaquent (sandy over loamy, mixed, mesic).
Symbols of mapping units:	Kg3

<u>Environmental factors</u>

Geographical distribution:	Scattered small areas along the eastern side of dune set 3 between Parera road and East-West Access road.
Parent material:	Aeolian sand over alluvial silts and clays.
Parent rock:	Greywacke/argillite and minor Tertiary sediments.
Physiographic position:	Toeslopes of dune set 3 where aeolian sand has blown across previously low lying boggy land.
Slope class:	Gently undulating to easy rolling.
Range of slope:	Most slopes less than 3°, up to 10°.
Vegetation:	
Original;	Swamp vegetation buried by sand.
Present;	Improved pasture, rushes.
Range of elevation:	1 -6m.
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Imperfectly to very poorly drained.
Soil moisture class:	Aquic.
Permeability:	Low.
Flooding:	
Frequency;	Before construction of stopbanks (designed for 50 year return period flood), would have flooded most years.
Duration;	Few days to week/s as slightly higher than surrounding land.
Erosion:	
Type;	Wind
Severity;	Moderate under pasture.

<u>Morphological and Chemical features</u>

Characteristic profile features

Mottled sandy soils (including low chroma mottles), overlying silts dominated by low chroma colours. Peat or peaty loam may have been buried the encroaching sand.

Typifying profile (#41)

Apg	20cm	Dull yellowish brown (10YR 4/3); loose loamy sand; weak medium nut structure; slightly sticky and slightly plastic; abundant roots.
Cr	30cm	Brown (10YR 4/4) and grey (10Y 6/1); loose loamy sand; single grain structure; non sticky and non plastic; common roots;
2Cr	20cm	Greyish yellow brown (10YR 5/2); firm; silty clay; massive; sticky and plastic; contains common sedge and grass organic material which resembles wet straw.
3O	20cm	Black (10YR 2/1); firm massive peat; sticky and plastic; few roots.
4Cr	on	Greenish grey (10G 6/1); firm massive silty clay with yellowish brown (10YR 5/6) plant remains; sticky and plastic.

Range of profile features (# of observations - 4)

Topsoil may or may not have ochreous mottles.
Topsoil sits directly over Cg or Cr horizon, generally sandy textured.
Peat, if present is usually found at approximately 60cm depth.

Similar soils and distinguishing features

SPC-I — Textures dominated by silts and clays with no sandy topsoil.

Chemical data — Not assessed.

Limitations and potentials for use

Area insignificant, therefore not assessed.

Land use ratings — Area insignificant, therefore not assessed.

Soil profile class I

Reference\classification

Soil name:	Pukeo clay loam.
County:	Featherston
Reference:	
Original set;	Kairanga loam etc, 2a.
NZSB Rec. 40;	Pukeo clay loam (Ahikouka silt loam on map). On the map accompanying NZSB Record 40 Pukeo clay loam and Ahikouka silt loam were transposed, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed. Pukeo clay loam soils have brownish grey clay loam topsoils overlying yellowish grey clay loam, on silt and clay sediments.
This survey;	Kept consistent with description in SB Record 40. i.e. gleyed recent soils (A/C profiles) developed in rapidly accumulating silts and clays sediments.
Classification:	
NZ Genetic;	Rapidly accumulating gleyed recent soil from alluvium.
Taxonomy;	Typic Fluvaquent (fine clayey, mixed, mesic)
Symbols of mapping units:	Pu1

Environmental factors

Geographical distribution:	Large extent between dune sets 1 and 2. Main area bounded to the south by the East-West Access road, to the west by the old Ruamahanga river channel, to the north by Parera road and the northeast by Boggy Pond and Mathew's Lagoon wildlife reserves. Thought to be the main soil type inside the reserves, although these were not surveyed. A smaller area extends northwestwards of the Oporua floodway for about 1 500m, bounded to the east and west by dune set 2 and the sandbank respectively.
Parent material:	Alluvial silts and clays.
Parent rock:	Greywacke/argillite and minor Tertiary sediments.
Physiographic position:	Around and between lagoons and drained lagoon beds. Part of the lower floodplain/delta of the Ruamahanga River, including infilled lake basins.
Slope class:	Gently undulating.
Range of slope:	Less than 5°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Improved and developing pasture, rushes and cabbage trees common. Also barley cropping.
Range of elevation:	0 - 4m.
Land use:	Barley, grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Poorly to very poorly drained.
Soil moisture class:	Aquic.
Permeability:	Low.

Flooding:	
Frequency;	Prior to the building of stopbanks (designed for 50 year return period flood) flooded 2 - 3 times a year. Still localised flooding due to ponding of rainfall.
Duration;	Ponding can persist for several days due to the low permeability of the clays. Flooding from the river and/or lake could last for days to weeks, because of the low elevation and proximity to the lake margins.
Erosion:	
Type;	Nil.
Severity;	NA

Morphological and Chemical features

Characteristic profile features

Poorly drained low lying soils, textures dominated by silts and clays. Topsoils are often mottled, subsoils have low chroma colours and mottles, often to the surface, with ochreous iron staining seen in root channels. Soils lack a structured B horizon, they are massive and firm to very firm.

Typifying profile (#20)

Apg	18cm	Greyish yellow brown (10YR 4/2); friable; silty clay loam; few small distinct yellowish brown (10YR 5/8) mottles; sticky and plastic; coarse nuts breaking to fine nut and crumb structure; abundant roots; indistinct straight boundary.
ACg	5cm	Yellowish grey to dark yellowish grey (2.5Y 5/1-5/2); friable to firm; silty clay; distinct to prominent fine yellowish brown (10YR 5/8) mottles; sticky and plastic; very coarse block structure; many roots; indistinct straight boundary.
Cg	39cm	Light olive grey (2.5Y 7/1) and yellowish brown (10YR 6/8-5/8) mottled; very firm; silty clay; sticky and plastic; massive; common to few roots; indistinct straight boundary.
Cr	33cm	Light olive grey to olive grey (2.5 7/1-6/1); very firm; silty clay; common prominent fine yellowish brown (10YR 5/8) mottles; sticky and plastic; massive; no roots; diffuse boundary.
2Cr	on	Light olive grey to olive grey (2.5GY 7/1-6/1); firm; sandy clay loam; common prominent fine yellowish brown 10YR 5/8) mottles; massive; no roots.

Range of profile features (# of observations - 36)

Thickness of the topsoil varies between 12 and 40cm.
Texture ranges from silty clay to fine sandy clay loam.
Topsoil varies from pale to dark (10YR 4/2-3/2) and may or may not be mottled.
AC horizon sometimes contains charcoal. In places black and/or brick red colours indicate where cabbage tree stumps were burnt.
May overlie sandy textured material at depth, ie greater than 80-90cm.

Similar soils and distinguishing features

SPC-J	Lack topsoils. In hollows of ephemeral or drained lagoons and may contain buried freshwater mussel shells.
SPC-W	Texture dominated by sand.
SPC-T	Silts and clays overlie sand, usually at 50cm depth. Show layering of sand/sandy clay/silty clay sediments deposited by flood events.

Chemical data

pH	Moderately acid to near neutral.
C%	Low to very low.
N%	Low
C/N ratio	Low
inorganic P	Very high
organic P	Medium to high

Limitations and potentials for use

Pasture;	Limitations of drainage and nutrients.
Cropping;	Limitations of subsoil pans and drainage impediments.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	2B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	2

Soil profile class J

Reference\classification

Soil name:	Te Hopai clay loam
County:	Featherston
Reference:	
Original set;	NA
NZSB Rec. 40;	Under water at time of survey, as lagoons had not yet been drained.
This survey;	Central concept is that of a gleyed soil, exposed by the draining of shallow ponds and lagoons, that has not yet had time to form a darkened friable topsoil.
Classification:	
NZ Genetic;	Rapidly accumulating gley recent soil from alluvium.
Taxonomy;	Typic Haplaquent (fine clayey, mixed, mesic)
Symbols of mapping units:	Th1

Environmental factors

Geographical distribution:	Small localised areas between the lake margin and boundaries formed by the old Ruamahanga river channel, East-West Access road, and dune set 2.
Parent material:	Lacustrine silts and clays.
Parent rock:	Greywacke/argillite and minor Tertiary sediments.
Physiographic position:	Hollows previously occupied by shallow ponds and lagoons. Recently drained. (last 5-10 years)
Slope class:	Flat to gently undulating.
Range of slope:	Mostly 0-2°, few up to 5°.
Vegetation	
Original;	Previously underwater.
Present;	Rushes, reeds, thistle, rough pasture.
Range of elevation:	< 1m.
Land use:	Grazing for sheep and cattle. Feed crops.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Very poorly to poorly drained.
Soil moisture class:	Aquic.
Permeability:	Low.
Flooding:	
Frequency;	Ponding causes surface flooding several times each winter, or even after high intensity summer rain.
Duration;	Few days to weeks, as not all hollows are drained, and natural permeability is low.
Erosion:	
Type;	Nil.
Severity;	NA

Morphological and Chemical features

Characteristic profile features

No A horizon, though organic darkened layer may be present due to pugging mixing litter layer in with top few centimetres of soil. Textures are dominated by silts and clays. Low chroma colours present to the surface.

Typifying profile (#23)

Cr	45cm	Yellowish grey to greyish yellow (2.5Y 6/1-6/2); firm; silty clay; many fine to medium distinct yellowish brown (10YR 5/6) mottles; especially down root channels; sticky and plastic; very coarse weak blocky structure to massive; abundant roots.
Cr2	on	Yellowish grey to greyish yellow (2.5Y 6/1-6/2); firm; clay; distinct yellowish brown mottles (10YR 5/6); sticky and plastic; massive; common to few roots. *Freshwater mussel shells between 30 and 50cm.

Range of profile features (# of observations - 19)

Litter may be present at surface.
Textures may be slightly sandy, ie fine sandy clay loam.
May overlie sand at depth, ie deeper than 80cm.
May have reduced horizons with no ochrous mottling.

Similar soils and distinguishing features

SPC-E	Subsoils have sandy textures.
SPC-I	Have A horizons.
SPC-W	Kumenga sand, swale phase; Texture sandy throughout.

Chemical data

pH	Moderately acid to slightly alkaline.
C%	Very low.
N%	Low
C/N ratio	Very low.
inorganic P	Very high
organic P	Medium to low

Limitations and potentials for use

Pasture;	Limitations of subsoil pans and drainage.
Cropping;	Limitations of wet low-lying land that is not easily drained.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of low actual or potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	3
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	3

Soil profile class K

Reference\Classification

Soil name:	Ahikouka silty clay loam on sand.
County:	Featherston
Reference:	
Original set;	Manawatu loam, silt loam and clay loam, 1.
NZSB Rec. 40;	Ahikouka silt loam (Pukeo clay loam on map) On the map accompanying NZSB Record 40 Pukeo clay loam and Ahikouka silt loam were transposed, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed. Ahikouka silt loam is described as having dark brownish topsoil, on a greyish yellow mottled silt loam horizon, on grey silty alluvium.
This survey;	Name 'Ahikouka' has been retained for soils of the slowly accumulating floodplain, and four phases recognised. Ahikouka silty clay loam on sand is characterised by a dark topsoil on a mottled silty clay loam horizon containing soft concretions, over gleyed alluvium.
Classification:	
NZ Genetic;	Slowly accumulating gleyed recent soil from alluvium.
Taxonomy;	Aeric Haplaquept (fine loamy over sand, mixed, mesic)
Symbols of mapping units:	Ak3

Environmental factors

Geographical distribution:	On southern part of the plain between dune sets 1 and 2. Bounded to the southwest by the channel in Oporua floodway, extends northeastwards between Kahutara road and dune set 2, to beyond Judds road.
Parent material:	Alluvial silts and sands.
Parent rock:	Greywacke/argillite, with minor Tertiary sediments.
Physiographic position:	Slowly accumulating floodplain of the lower Ruamahanga River between dune sets 1 and 2.
Slope class:	Easy rolling.
Range of slope:	Less than 5°, aspect east.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Mostly improved pasture of ryegrass and clover, also barley and fodder crops.
Range of elevation:	3 - 10m.
Land use:	Intensive grazing of sheep and cattle, feed crops.
Rainfall range:	Annual average 1 000 - 1 200mm.
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Imperfectly to very poorly drained.
Soil moisture class:	Ustic to aquic
Permeability:	Moderate to slow.
Flooding:	
Frequency;	Before stopbanks built (designed for 50 year return period flood) probably flooded 2 - 5 times per decade. Land inside the Oporua floodway still flooded regularly.
Duration;	Few days to a week as on relatively high ground.
Erosion:	
Type;	Nil.
Severity;	NA

Morphological and Chemical features

Characteristic profile features

Dark friable topsoil over B horizon which typically contains large round soft concretions. The B horizon overlies mottled to gleyed sands. Silty/clay lenses may occur through the lower part of the profile. At depths greater than 1m profile overlies layers of silts and organic matter on blue-grey sandy mud.

Typifying profile (#78)

Ap	30cm	Brownish black (10YR 3/1-3/2); friable; silty clay loam; sticky and plastic; moderately developed medium to fine nut and crumb structure; abundant roots; distinct straight boundary.
Bwc	15cm	Dull yellowish brown (10YR 4/3); friable; silty clay loam; bright brown (7.5YR 4/6-5/8) round soft concretions; moderately developed medium nut and block structure; sticky and plastic; many roots; straight distinct boundary.
2Cg	35cm	Brown (7.5YR 4/6) and olive grey (2.5GY 6/1); firm; sand; coarse blocky structure to massive; with stones (5%,less than 5mm), non sticky and non plastic; few roots; indistinct boundary.
2Cr	15cm	Olive grey (2.5GY 6/1) and yellowish brown (10YR 5/8); firm; sand; non sticky and non plastic; massive; no roots; straight distinct boundary.
3Cr	on	Grey (N6/1) and bright yellowish brown (10YR 5/6) mottled; sandy clay; massive; sticky and plastic; no roots.

Range of profile features (# of observations - 18)

Colour of topsoil varies from 10YR 3/2 -4/3.
Topsoil may contain ochreous mottles.
AB horizon may or may not be present.
Concretions may be dark to bright brown, small to large, soft to very firm. Found in AB and B horizons, occasionally in the underlying sands.
Ironstone may be found at the base of the B horizon, overlying the sandy subsoil.
Percentage of low chroma colours in subsoils increases towards the dunes, also in lower parts of the landscape.
May contain thin (less than 5cm) lenses of small pebbles (less than 1cm diameter).

Similar soils and distinguishing features

SPC-P	Topsoil is paler, and almost always have an AB horizon. Not based on sand by approximately 50cm but generally have a sandy clay loam texture to over 1m.
SPC-D	Texture sandy throughout and rarely contains concretions.

Chemical data

pH	Moderately to slighty acid.
C%	Very low
N%	Low to very low
C/N ratio	Low
inorganic P	High
organic P	Medium to high

Limitations and potentials for use

Pasture;	Limitations of drainage and nutrients.
Cropping;	Limitations of drainage.
Horticultural;	Limitations of poor drainage.
Forestry;	Slight limitations of soil drainage which may limit the establishment of some species.
Urban;	Soils of flat and rolling land with minimal to slight limitations for urban use.
Value for food production;	Soils of high potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	1C
Horticultural;	2A
Forestry;	1B
Urban;	1
Value for food production;	1B

Soil profile class L

Reference\classification

Soil name: Ahikouka stony silty clay loam.
County: Featherston
Reference:
Original set; Tukituki sandy loam, stony gravel etc.
NZSB Rec. 40; Ahikouka silt loam (Pukeo clay loam on map)
On the map accompanying NZSB Record 40 Pukeo clay loam and Ahikouka silt loam were transposed, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed.
Ahikouka silt loam is described as having dark brownish topsoil, on a greyish yellow mottled silt loam horizon, on grey silty alluvium.
This survey; Name 'Ahikouka' has been retained for soils of the slowly accumulating floodplain, and three phases recognised.
Ahikouka stony loam is stony to very stony in the upper 45cm of the profile.
Classification:
NZ Genetic; Slowly accumulating gleyed recent soil from alluvium.
Taxonomy; Humic Haplaquept (coarse loamy, mixed, mesic).
Symbols of mapping units: Ak2

Environmental factors

Geographical distribution: Area around the intersection of Judds road and Kahutara road.
Parent material: Alluvial/fluvial silts, sands and gravels.
Parent rock: Greywacke/argillite with minor Tertiary sediments.
Physiographic position: On part of the slowly accumulating floodplain of the lower Ruamahanga River, between dune sets 1 and 2.
Slope class: Flat to gently undulating.
Range of slope: Less than 5°.
Vegetation:
Original; Podocarp and dicotylous forest.
Present; Improved pasture, dominantly ryegrass and clover.
Range of elevation: 3 - 6m.
Land use: Dairying and beef fattening.
Rainfall range: Annual average 1 000 - 1 200mm
Temperature range: Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime: mesic
Soil drainage class: Imperfectly drained.
Soil moisture class: Ustic.
Permeability: Moderate.
Flooding:
Frequency; Before stopbanks built (designed for 50 year return period flood) probably flooded 3 - 5 times a decade.
Duration; Few days to a week.
Erosion:
Type; Nil.
Severity; NA

Morphological and Chemical features

Characteristic profile features

Generally has a dark friable topsoil, becoming stony to very stony at less than 45cm depth. Stoniness may persist down the profile, or may be underlain by sand at depth. The stony horizon must be thick enough to make cultivation difficult, ie 20cm.

Typifying profile (#57)

Ah	23cm	Brownish black (10YR 3/2); friable; sandy clay loam; moderately developed nut and block structure; abundant roots; wavy diffuse boundary.
Bcg	19cm	Greyish yellow brown (10YR 5/2); friable; sandy loam; with brown (10YR 4.6) concretions; moderately developed coarse nut and block structure; abundant roots; straight distinct boundary.
2Cu	22cm	Brown (7.5YR-10YR 4/6); loamy sand; very stony (more than 30% stones); non sticky and non plastic; many roots; sharp straight boundary.
3Cr	1cm	Grey clay lens; sticky and plastic; massive.
4Cr	25cm	Brown (7.5YR 4/6); loose; loamy sand; grey (7.5Y 6/1) mottles; stony (20% stones); non sticky and non plastic; few roots; straight distinct boundary.
5Cr	on	Skeketal (clast supported, more than 70%) gravel; (2.5Y 6/3) dull greyish yellow coarse sand between gravels; non sticky and non plastic.

Range of profile features (# of observations - 7)

Horizons than overlie and underlie the stony horizon may contain concretions.
Thin (less than 5mm) ironpans sometimes present.
A and B horizons may be free of stones or have less than 5% stones, ie 'with stones'.
B horizons may be stony and the A and C horizons be free of stones.
Silt layers/lenses may occur in the subsoil.
Stones range in size from less than 1cm to 5-7cm, i.e. pebbles.

Similar soils and distinguishing features

SPC-K	Commonly stony layers thin and discontinuous. Although subsoils may be stony to very stony the A snd B horizons always have less than 5% stones thus causing no impediment to agricultural practices.
SPC-G	Have more than 5% stones in the top 20cm with the stony layer being 30 - 40cm thick. Ahikouka stony loam has less than 5% stones in the top 20cm but greater than 5% from 20-45cm.

Chemical data Not assessed.

Limitations and potentials for use

Pasture;	Limitations of drainage and nutrients.
Cropping;	Limitations of drainage.
Horticultural;	Limitations of poor drainage.
Forestry;	Slight limitations of soil drainage which may limit the establishment of some species.
Urban;	Soils of flat and rolling land with minimal to slight soil limitations to urban use.
Value for food production;	Soils of high potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	1C
Horticultural;	2A
Forestry;	1B
Urban;	1
Value for food production;	1B

Soil profile class M

Reference\classification

Soil name:	Kahutara sand.
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Manihera sand. Sand soils on hummocky dunes east of Lake Wairarapa that have brownish black topsoils on yellowish-brown sand.
This survey;	Name 'Manihera sand' kept for dune soils with A/C profiles. 'Kahutara sand' introduced to denote those soils developed on dune set 1 having A/Bw/BC/C profiles.
Classification:	
NZ Genetic;	Moderately leached central yellow brown sand.
Taxonomy;	Typic Ustipsamment (sandy, mixed, mesic)
Symbols of mapping units:	Ka

Environmental factors

Geographical distribution:	On the high dunes furthest from the lake extending from northeast to southwest across Kahutara road.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On crests and sides of dune set 1.
Slope class:	Easy rolling to moderately steep - steep.
Range of slope:	Less than 5° on the crests, up to 30° on the sides.
Vegetation:	
original;	Podocarp and dicotylous forest.
present;	Manuka scrub and dryland pasture, (browntop, ryegrass, sweet vernal).
Range of elevation:	Up to 40m.
Land use:	Grazing for dairy cattle, beef cattle and sheep.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	mesic
Soil drainage class:	Excessively drained.
Soil moisture class:	Ustic.
Permeability:	Very rapid.
Flooding:	
Frequency;	Nil.
Duration;	NA
Erosion:	
Type;	Not normally subject to wind erosion, except where disturbed by earthworks.
severity;	Slight.

Morphological and Chemical features

Characteristic profile features

Dark, friable, well structured sandy topsoil over a B horizon with moderately developed structure over BC and C horizons developed in sand. Unmottled.

Typifying profile (#313)

Ah	10cm	Brownish black (10YR 3/2); friable; sandy clay loam; sticky and plastic; moderately developed medium nut and block structure breaking to fine nut and crumb structure; many roots; indistinct boundary.
Bw	26cm	Dull yellowish brown (10YR 4/3); friable; sandy loam; slightly sticky and slightly plastic; weak to moderately developed coarse nut and block structure; common roots; indistinct boundary.
BC	27cm	Yellowish brown (2.5Y 5/3); loose sand; non sticky and non plastic; single grain structure; common roots; indistinct boundary.
C	on	Yellowish brown (2.5Y 5/4); loose; sand; non sticky and non plastic; single grain structure.

Range of profile features (# of observations - 3)

Depth of the A horizon varies with position on the dune, being thicker on the crest.
On sides of the dunes small scale slumps may have created buried profiles.

Similar soils and distinguishing features

SPC-B	Soil less well developed with weaker structure in the B horizon and lacking BC horizons.

Chemical data

pH	Moderately acid to near neutral.
C%	Very low
N%	Low to very low
C/N ratio	Medium
inorganic P	Very high
organic P	Medium

Limitations and potentials for use

Pasture;	Limitations of insufficient or excessive moisture.
Cropping;	Soils of hilly and steep land with very severe limitations to crop production - unsuitable.
Horticultural;	Soils of hilly and steep land with very severe soil limitations to horticultural use. Not suitable.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of hilly and steep land with moderate limitations to urban use. (Limitations are mainly of slope and erosion)
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	5A
Cropping;	4
Horticultural;	4
Forestry;	2B
Urban;	4
Value for food production;	2

Soil profile class P

Reference\classification

Soil name:	Ahikouka silty clay loam.
County:	Featherston
Reference:	
Original set;	Manawatu loam, silt loam and clay loam, 1.
NZSB Rec. 40;	Ahikouka silt loam (Pukeo clay loam on map) On the map accompanying NZSB Record 40 Pukeo clay loam and Ahikouka silt loam were transposed, shown on the slowly accumulating and rapidly accumulating floodplains respectively. Their positions should be reversed. Ahikouka silt loam is described as having dark brownish topsoil, on a greyish yellow mottled silt loam horizon, on grey silty alluvium.
This survey;	Name 'Ahikouka' has been retained for soils of the slowly accumulating floodplain, and three phases recognised. Ahikouka silty clay loam has brown friable topsoil, on a dull yellowish and grey mottled horizon, on grey and yellowish brown mottled alluvium.
Classification:	
NZ Genetic;	Slowly accumulating gleyed recent soil from alluvium.
Taxonomy;	Aeric Haplaquent (fine loamy, mixed, mesic)
Symbols of mapping units:	Ak1

Environmental factors

Geographical distribution;	In the vicinity of Whareroto road, bounded to the north and east by Mangatete stream and Kahutara road respectively.
Parent material:	Alluvium.
Parent rock:	Greywacke/argillite and minor Tertiary sediments.
Physiographic position:	At northern end of the slowly accumulating floodplain of the lower Ruamahanga River, between dune sets 1 and 2.
Slope class:	Flat to gently undulating.
Range of slope:	Most less than 2°, all less than 5°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Improved ryegrass and clover pasture, also maize and barley crops.
Range of elevation:	2 - 6m.
Land use:	Grazing for sheep and cattle, maize and barley cropping.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	mesic
Soil drainage class:	Imperfectly to poorly drained.
Soil moisture class:	Aquic.
Permeability:	Low.
Flooding:	
Frequency;	Probably flooded 2 to 3 times per decade before stopbanks built (designed for 50 year return period flood).
Duration;	Few days.
Erosion:	
Type;	Nil.
Severity;	NA

Morphological and Chemical features

Characteristic profile features

Friable brown topsoil, usually unmottled; over mottled B horizon (including low chroma mottles) on mottled C horizon. Typically silty clay loam texture grading to sandy clay loam down the profile.

Typifying profile (#262)

Ap	22cm	Dull yellowish brown (10YR 4/3); friable; silty to fine sandy clay loam; sticky and plastic; well developed medium nut and crumb structure. many roots; indistinct boundary.
Bgc	58cm	Dull yellow orange (10YR 6/3); firm; fine sandy clay loam; light grey (10Y 7/1) and dark brown (7.5YR 3/4) mottles; few small hard dark concretions; moderately to well developed coarse nut and block structure; sticky and plastic; common roots; diffuse boundary.
2Crc	on	Bright yellowish brown (10YR 5/6) and grey (10Y 7/1) mottled; firm; sandy clay loam; few hard concretions; sticky and plastic.

Range of profile features (# of observations - 14)

May overlie sands at depths greater than 80cm.
AB horizon may or may not be present.
Concretions may or may not be present.
B horizon varies in thickness from 15 to 50cm.

Similar soils and distinguishing features

SPC-K — Can sit on sand from 50cm. Structure not quite as well developed.

Chemical data

pH	Moderately to slightly acid.
C%	Very low
N%	Low to very low
C/N ratio	Medium
inorganic P	High
organic P	Medium

Limitations and potentials for use

Pasture:	Minimal limitations of drainage and nutrients.
Cropping:	Slight limitations of drainage.
Horticultural:	Moderate limitations of poor drainage.
Forestry:	Slight limitations of soil drainage which may limit the establishment of some species.
Urban:	Soils of flat and rolling land with minimal to slight soil limitations to urban use.
Value for food production:	Soils of high potential value for food production.

Land use ratings

Pasture:	1B
Cropping:	1C
Horticultural:	2A
Forestry:	1B
Urban:	1
Value for food production:	1B

Soil profile class Q

Reference\classification

Soil name:	Manihera mottled sand.
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Kumenga mottled sand: Sandy soils in depressions between dunes, which have black topsoils overlying grey sand with yellowish brown mottles.
This survey;	'Kumenga mottled sand' retained for soils with A/C profiles mottled up to the topsoil. 'Manihera mottled sand' introduced to describe dune soils with A/C profiles mottled at depths greater than 45cm.
Classification:	
NZ Genetic;	Moderately leached, gleyed yellow brown sand.
Taxonomy;	Aquic Ustipsamment (sandy, mixed, mesic)
Symbols of mapping units:	Mn2

Environmental factors

Geographical distribution:	On dune set 3 which parallel Parera road between the old Ruamahanga river channel and Oporua floodway.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On backslopes and toeslopes of dune set 3. Also on long flat noses of dunes.
Slope class:	Easy rolling to rolling.
Range of slope:	2° - 15°.
Vegetation:	
original;	Podocarp and dicotylous forest.
present;	Pasture grasses, rushes, cabbage trees.
Range of elevation:	2 - 5m.
Land use:	Grazing for sheep and lambs, some cattle.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Well drained.
Soil moisture class:	Ustic.
Permeability:	Rapid.
Flooding:	
frequency:	Nil.
Duration;	NA
Erosion:	
type;	Not normally subject to wind erosion under pasture.
Severity;	Moderate.

Morphological and Chemical features

Characteristic profile features

Profile dominated by sandy textures. Brown topsoil over massive pale subsoil, becoming mottled with ochreous and low chroma mottles below a depth of 45cm.

Typifying profile (#182)

F-M4cm		
Ahp	20cm	Brownish black (10YR 3/2); friable; sandy clay loam; sticky and plastic; moderately developed medium-coarse block structure; many roots; diffuse boundary.
2Cu	31cm	Dull yellowish brown (10YR 5/3); sandy loam; firm to loose; sticky and plastic; massive; common roots; diffuse boundary.
3Crc	on	Grey (7.5Y 5/1); firm; sandy clay loam; common large soft orange to bright brown (7.5YR 6/8-5/8) concretions and bright brown mottles; massive; sticky and plastic; few roots.

Range of profile features (# of observations - 6)

May or may not have an AC horizon.
Concretions are uncommon.

Similar soils and distinguishing features

SPC-X	Mottled only at depths greater than 90cm.
SPC-W	Mottled to the surface.
SPC-C	Profile has B horizon which is generally unmottled.
SPC-H	Mottled to the surface.

Chemical data

pH	Moderately to slightly acid
C%	Medium to low
N%	Medium
C/N ratio	Medium to low
inorganic P	Very high
organic P	Medium to very low

Limitations and potentials for use

Pasture;	Limitations of insufficient moisture, and to a lesser extent, nutrients.
Cropping;	Soils of hilly and steep land with very severe limitations to crop production - unsuitable.
Horticultural;	Soils of hilly and steep land with very severe soil limitations to horticultural use - not suitable.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of hilly and steep land with moderate limitations to urban use. (Limitations are mainly of slope and erosion)
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	2A
Cropping;	4
Horticultural;	4
Forestry;	2B
Urban;	4
Value for food production;	2

Soil profile class S

Reference\classification

Soil name:	Ruamahanga sand.
County:	Featherston
Reference:	
Original set;	Esk sand,1b.
NZSB Rec. 40;	Ruamahanga sand. Found along most rivers and streams on free-draining floodplain with frequent deposition of sandy deposits. Described as greyish brown sand over grey loose sand, gravel and stones.
This survey;	Name retained for lake shore sand.
Classification:	
NZ Genetic;	Rapidly accumulating recent soil from alluvium.
Taxonomy;	Typic Psammaquent (sandy, mixed, mesic)
Symbols of mapping units:	R

Environmental factors

Geographical distribution:	Sandy foreshore of the eastern side of Lake Wairarapa, between high winter and low summer limits.
Parent material:	Lacustrine sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	Sand bank exposed by low water levels of Lake Wairarapa. Inundated by high winter lake levels and 'set-up'.
Slope class:	Flat to gently undulating.
Range of slope:	Less than 5°, aspect west.
Vegetation:	
Original;	NA - recently deposited.
Present;	Slightly raised areas have discontinuous grass, clover and flatweed cover.
Range of elevation:	< 2m.
Land use:	Used by waterfowl (ducks, swan, waders etc) for resting and feeding. Extensive grazing of sheep and cattle through the summer months.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Poorly to very poorly drained.
Soil moisture class:	Aquic.
Permeability:	Good.
Flooding:	
Frequency;	At least annually, up to eight times a year.
Duration;	Up to four months (semi-continuously) over winter.
Erosion:	
Type;	Subject to erosion and deposition by waves.
Severity;	Moderate.

Morphological and Chemical features

Characteristic profile features

Low chroma coloured massive sand with no topsoil.

Typifying profile (#148)

Cr	18cm	Grey to greyish olive (7.5Y 5/1-5/2); loose; sand; single grain; non sticky and non plastic; straight sharp boundary.
Cr2	on	Greyish olive (7.5Y 5/2) and grey (10Y 6/1); loose; sand; approximately 20% olive brown (2.5Y 4/6) mottles; single grain; non sticky and non plastic.

Range of profile features (# of observations - 8)

Whole profile may be mottled or unmottled.
Some profiles overlie dark olive grey to dark greenish grey sands.
Very sensitive sands at depth.
Dominated by 7.5Y, 5Y, 10Y hues, with 2.5Y and 7.5YR hues found in the mottles.

Similar soils and distinguishing features

SPC-W — Has topsoil and is set back from the lake shore.

Chemical data

pH	Slightly alkaline
C%	Very low
N%	Very low
C/N ratio	Very low
inorganic P	Very high
organic P	Medium

Limitations and potentials for use

Pasture;	Limitations of subsoil pans and drainage.
Cropping;	Limitations of low-lying land that is not easily drained.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of low actual or potential value for food production.

Land use ratings

Pasture;	3B
Cropping;	3B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	3

Soil profile class T

Reference\classification

Soil name:	Pukeo clay loam on sand.
County:	Featherston
Reference:	
Original set;	Manawatu loam, silt loam and clay loam, 1.
NZSB Rec. 40;	Ruamahanga sand. Found along most rivers and streams on free-draining floodplains with frequent deposition of sandy deposits. Described as greyish brown sand over grey loose sand, gravel and stones.
This survey;	'Ruamahanga sand' refers to sandy deposits,'Pukeo clay loam' to clayey deposits. Introduced the name 'Pukeo clay loam on sand' to describe soils which have textures dominated by silts and clays in the upper part of the profile, but by sand or regularly alternating layers of sand, sandy clay and clay in the subsoil.
Classification:	
NZ Genetic;	Rapidly accumulating gleyed recent soil from alluvium.
Taxonomy;	Typic Fluvaquent (fine loamy over sandy, mixed, mesic).
Symbols of mapping units:	Pu3

Environmental factors

Geographical distribution:	On Jury Island, and the northeastern side of the old Ruamahanga river channel.
Parent material:	Alluvial sands and silts.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	Delta/rapidly accumulating floodplain of the lower Ruamahanga River.
Slope class:	Flat to gently undulating.
Range of slope:	Less than 2°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Ryegrass and clover pasture.
Range of elevation:	1 - 4m.
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Poorly drained.
Soil moisture class:	Aquic.
Permeability:	Moderate to poor.
Flooding:	
Frequency;	Stopbanks designed for 50 year return period flood. Prior to diversion, at least annual flooding, and still floods several times per decade whenever lake levels are high.
Duration;	Few days, prior to diversion semi-continuously for several weeks through the winter months.
Erosion:	
Type;	River bank.
Severity;	Very slight.

Morphological and Chemical features

Characteristic profile features

AC profile with low chroma mottling at depths less than 45cm, often to the surface. Top 30-60cm dominated by silt and clay textures, sandy subsoils.
May show layering of sediments, ie clay/sandy clay/sand, representing past flood events.

Typifying profile (#198)

Ap 20cm		Dull yellowish brown (10YR 4/3-5/3); friable; silty clay loam; yellowish brown (10YR 5/8) mottles especially in root channels; sticky and plastic; strongly developed fine to medium nut and crumb structure; many roots; distinct straight boundary.
Cr 25cm		Olive grey (2.5GY 6/1); firm; fine sandy clay loam; yellow brown (10YR 5/8) mottles; sticky and plastic; massive; common roots.
2Cr	15cm	Olive grey (2.5GY 6/1); loose; sand; common yellow brown (10YR 5/8) mottles; non sticky and non plastic; single grain structure; few roots; distinct boundary.
3Cr	on	Olive grey (2.5GY 6/1) and yellowish brown (10YR 5/8) profusely mottled alternating; clay/sandy clay/sand; firm; massive.

Range of profile features (# of observations - 11)

Ah horizon may be mottled.
Cr horizons have a wide range of textures, generally normally graded.
May contain plant remains at depth.
Cm horizons may be present, these are usually thin iron pans less than 2mm thick.

Similar soils and distinguishing features

SPC-Z	Profile sandy throughout, on toeslopes of aeolian dunes. Intergrades between this soil and Pukeo clay loam on sand occasionally found.
SPC-I	Profiles lack sandy layers, and laminations.
SPC-J	Lacks an A horizon, often contain shells.

Chemical data

pH	Slightly acid to near neutral.
C%	Low to very low
N%	Low
C/N ratio	Low
inorganic P	Very high
organic P	Medium to low

Limitations and potentials for use

Pasture;	Limitations of drainage and nutrients.
Cropping;	Limitations of subsoil pans and drainage impediments.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	1B
Cropping;	2B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	2

Soil profile class V

Reference\classification

Soil name:	Parera sand.
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Kumenga mottled sand. Mottled sand soils found in depressions between hummocky dunes east of Lake Wairarapa. Have a black A horizon over grey sand with yellowish brown mottles.
This survey;	'Kumenga mottled sand' kept for mottled sand soils with A/C profile development. 'Parera sand' introduced for very young unmottled dune soils with weak soil profile development.
Classification:	
NZ Genetic;	Weakly leached central yellow brown sand.
Taxonomy;	Typic Ustipsamment (sandy, mixed, mesic)
Symbols of mapping units:	Pa

Environmental factors

Geographical distribution:	Small extent of hummocky dunes immediately behind the sandy foreshore of Lake Wairarapa. Parallel the southwestern end of Parera road.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On well drained crests and shoulders of dune set 4.
Slope class:	Easy rolling to moderately steep.
Range of slope:	Less than 20°, most less than 10°.
Vegetation:	
Original;	Very young, little or no previous vegetation.
Present;	Lupin, gorse, grass and weeds.
Range of elevation:	
Land use:	Extensive cattle grazing.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	mesic
Soil drainage class:	Somewhat excessively drained.
Soil moisture class:	Ustic.
Permeability:	Rapid.
Flooding:	
Frequency;	Dune set 4 could be inundated by especially high lake levels. ie by diversion of flow from the Ruamahanga River through the Oporua floodway.
Duration;	Few hours to few days depending on the magnitude of the event.
Erosion:	
Type;	Creep and wind erosion; wave damage by high lake levels.
Severity;	Moderate.

Morphological and Chemical features

Characteristic profile features

Profile has a thin topsoil with very weak structure on massive loose sands. ie AC profile. Texture sandy throughout.

Typifying profile (#319)

Ah	4cm	Brownish black (10YR 2/2); friable to loose; loamy sand; very weak fluffy crumb structure; non sticky and non plastic; many roots; straight distinct boundary.
Cu	on	Greyish olive (5Y 4/2); loose; sand; non sticky and non plastic; single grain structure; many to few roots.

Range of profile features (# of observations - 3)

Litter layers often present on the surface.
Mottling at depth may occur on lower slopes.

Similar soils and distinguishing features

SPC-M	On dune set 1.	A/B/BC/C profile.
SPC-B	On dune set 2.	A/B/C profile.
SPC-X	On dune set 3.	Friable topsoil with nut and block structure. In the C horizon 2.5Y hues dominate.

Chemical data

pH	Slightly acid.
C%	Very low
N%	Very low
C/N ratio	Medium to low
inorganic P	Very high
organic P	Medium

Limitations and potentials for use

Pasture;	Limitations of insufficient moisture - limitations of frequent dryness.
Cropping;	Limitations of shallow profiles, with serious moisture deficiency.
Horticultural;	Limitations of excessive drainage.
Forestry;	Limitations of coarse sandy texture and probably nutrient deficiencies as well.
Urban;	Soils of flat and rolling land with severe limitations to urban use.
Value for food production;	Soils of low actual or potential value for food productions.

Land use ratings

Pasture;	2A - 3E
Cropping;	3A
Horticultural;	3B
Forestry;	2B
Urban;	3
Value for food production;	3

Soil profile class W

Reference\classification

Soil name:	Kumenga sand, swale phase.
County:	Featherston
Reference:	
Original set;	Whananaki sand, 23b.
NZSB Rec. 40;	Kumenga mottled sand. Mottled sand soils found in depressions between hummocky dunes east of Lake Wairarapa. Have a black A horizon over grey sand with yellowish brown mottles.
This survey;	Kumenga sand retained for sand soils with A/C profiles mottled to the A horizon. Two phases were recognised, one on toeslopes of dunes and on low lying dunes, the other in swales and on sand plains between dunes. Kumenga sand - swale phase, is a gleyed sandy soil with mottling (including low chroma mottles) to the surface.
Classification:	
NZ Genetic;	Moderately leached gleyed yellow brown sand.
Taxonomy;	Mollic Psammaquent (sandy, mixed, mesic)
Symbols of mapping units:	Kg2.

Environmental factors

Geographical distribution:	Moderate area extending northeast to southwest immediately behind the lake margin (foreshore). Found in the vicinity of Parera road south of Oporua floodway, and bounded to the east by dune set 2 further north.
Parent material:	Aeolian sand, and water laid sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	Swales between dunes, and low hummocky land between dune sets 3 and 4.
Slope class:	Easy rolling.
Range of slope:	Mainly 2-5°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Pasture, rushes, dandelion, cabbage trees.
Range of elevation:	< 3m.
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	mesic
Soil drainage class:	Poorly drained.
Soil moisture class:	Aquic.
Permeability:	Rapid to moderate.
Flooding:	
Frequency;	Stopbanks designed for 50 year return period flood, though flooding and ponding occurs most winters and spring.
Duration;	Few days to weeks as water would pond in low areas until removed by evaporation and drop in lake levels.
Erosion:	
Type;	none
Severity; NA	

Morphological and Chemical features

Characteristic profile features

Soils have A horizons over massive C horizons. Profiles are mottled to the surface with subsoils usually gleyed. Textures are sandy throughout.

Typifying profile (#222)

Apg	12cm	Dull yellowish brown to dark brown (10YR 4/3-3/3); friable; sandy clay loam; few bright yellowish brown (10YR 5/8) mottles; sticky and plastic; moderately developed medium nut and block structure; common roots; straight to wavy distinct boundary.
Cr	19cm	Grey (7.5Y 5/1); loose; sand to loamy sand; common bright brown (7.5YR 5/8) mottles; non sticky and non plastic; single grain structure; common roots; indistinct boundary.
Cr2	on	Grey (7.5Y 6/1); loose; sand; few brown (7.5YR 4/3) mottles; non sticky and non plastic; single grain structure; few roots.

Range of profile features (# of observations - 23)

May contain concretions.
Range of textures, ie sandy loam, loamy sand, and sand.
May overlie silty or clay rich layers at depth, ie sandy clay to sandy clay loam at approximately 90cm, where small dunes cover muddy lake sediments.
Profiles near the old river channel may contain laminated sands and interbedded sandy clay and clay lenses/layers at depth as these grade into Pukeo clay loam on sand. If these layers are found at a depth greater than 80-90cm the soil is considered to be Manihera sand.

Similar soils and distinguishing features

SPC-T	Silts and clays over sand. Commonly show layering representing flood events.
SPC-E	Don't have A horizons, and textures are more silty and clay rich.
SPC-Z	Distinguished by position in the landscape.
SPC-D	Have B horizons.

Chemical data

pH	Moderately acid to near neutral.
C%	Very low
N%	Very low
C/N ratio	Low
inorganic P	Very high
organic P	Medium to low

Limitations and potentials for use

Pasture;	Limitations of drainage.
Cropping;	Limitations of subsoil pans and drainage impediments.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations for urban use.
Value for food production;	Soils of low to moderate actual or potential value for food production.

Land use ratings

Pasture;	1B - 3B
Cropping;	2B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	3

Soil profile class z

Reference\classification

Soil name:	Kumenga sand, dune phase.
County:	Featherston
Reference:	
Original set;	Patea sand, 23.
NZSB Rec. 40;	Kumenga mottled sand. Mottled sand soils found in depressions between hummocky dunes east of Lake Wairarapa. Have a black A horizon over grey sand with yellowish brown mottles.
This survey;	Kumenga sand retained for sand soils with A/C profiles mottled to the A horizon. Two phases were recognised, one on toeslopes of dunes and on low lying dunes, the other in swales and on sand plains between dunes. Kumenga sand - dune phase, is a gleyed sandy soil with mottles (including low chroma mottles) to below the A horizon.
Classification:	
NZ Genetic;	Moderately leached gleyed yellow brown sand.
Taxonomy;	Mollic Psammaquent (sandy, mixed, mesic).
Symbols of mapping units:	Kg1

Environmental factors

Geographical distribution:	Moderate area extending northeast to southwest immediately behind the lake margin (foreshore). Found in the vicinity of Parera road south of Oporua floodway, and bounded to the east by dune set 2 further north.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On toeslopes of dune set 3, and on low dunes less than 1m high.
Slope class:	Easy rolling.
Range of slope:	Up to 10°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Pasture, cabbage trees.
Range of elevation:	1 - 4m.
Land use:	Grazing for sheep and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°.
Soil temperature regime:	Mesic
Soil drainage class:	Poorly drained.
Soil moisture class:	Aquic.
Permeability:	Moderate.
Flooding:	
Frequency;	Stopbanks designed for 50 year return period flood. Toeslopes flooded infrequently when lake levels are very high.
Duration;	Few days until lake levels fall.
Erosion:	
Type;	Prone to wind erosion in dry summers if disturbed.
Severity;	Moderate.

Morphological and Chemical features

Characteristic profile features

A/C profile with sandy texture throughout. Dark brown friable topsoil which is usually unmottled. Distinct boundary to mottled and gleyed subsoils. There is generally a Cg horizon above gleyed (Cr) subsoils.

Typifying profile (#174)

Ap	30cm	Dark brown (10YR 3/4); friable; silty clay loam; sticky and plastic; moderately developed medium nut structure; common roots; distinct boundary.
Cg	10cm	Yellowish brown (10YR 5/6) and grey (7.5Y 5/1) mottled; loamy sand; weak very coarse block structure to massive; non sticky and non plastic; common roots; diffuse boundary.
Cr	on	Light brownish grey (7.5Y 7/1) and yellowish brown (10YR 5/6) mottled; loose; sand; non sticky and non plastic; single grain structure; few roots.

Range of profile features (# of observations - 7)

May or may not have a Cg horizon.
Topsoil usually unmottled.

Similar soils and distinguishing features;

SPC-W	Mottled to the surface and also distinguished by physiographic position. Has
SPC-D	Has a B horizon.
SPC-1	Dominated by silt and clay textures.
SPC-E	Lacks an A horizon and textures also more silt and clay rich.

Chemical data As for Kumenga sand swale phase.

Limitations and potentials for use

Pasture;	Limitations of drainage.
Cropping;	Limitations of subsoil pans and drainage impediments.
Horticultural;	Limitations of poor drainage and/or poor physical structure.
Forestry;	Limitations of poor drainage.
Urban;	Soils of flat and rolling land with severe limitations for urban use.
Value for food production;	Soils of low to moderate actual or potential value for food production.

Land use ratings

Pasture;	1B - 2B
Cropping;	2B
Horticultural;	3A
Forestry;	3C
Urban;	3
Value for food production;	2

Soil profile class X

Reference/classification

Soil name:	Manihera sand.
County:	Featherston
Reference:	
Original set:	Patea sand, 23.
NZSB Rec. 40:	Kumenga mottled sand. Mottled sand soils found in depressions between hummocky dunes east of Lake Wairarapa. Have a black A horizon over grey sand with yellowish brown mottles.
This survey;	'Kumenga sand' retained for sand soils with A/C profiles mottled to the A horizon. 'Manihera sand' retained for sandy soils on hummocky dunes with unmottled A/C profiles.
Classification:	
NZ Genetic:	Moderately leached central yellow brown sand.
Taxonomy:	Typic Ustipsamment (sandy, mixed, mesic).
Symbols of mapping unit:	Mn1

Environmental factors

Geographical distribution:	On dune set 3, which parallel Parera road, between the old Ruamahanga river channel and Oporua floodway.
Parent material:	Aeolian sand.
Parent rock:	Greywacke/argillite with minor Tertiary sediments.
Physiographic position:	On crests and sides of dune set 3.
Slope class:	Rolling to moderately steep-steep.
Range of slope:	5 - 30°.
Vegetation:	
Original;	Podocarp and dicotylous forest.
Present;	Pasture and cabbage trees.
Range of elevation:	4 -12m.
Land use:	Grazing for sheep, lambs and cattle.
Rainfall range:	Annual average 1 000 - 1 200mm
Temperature range:	Annual average 12.5°, monthly averages 8-17°
Soil temperature regime:	Mesic.
Soil drainage class:	Excessively drained.
Soil moisture class:	Ustic:
Permeability:	Very rapid.
Flooding:	
Frequency;	Nil.
Duration;	NA
Erosion:	
Type;	Creep, wind.
Severity;	Moderate.

Morphological and chemical features

Characteristic profile features

Dark friable topsoils over sand, ie A/C profiles. Commonly have AC horizons.

Typifying profile (#)

Ahp	12cm	Dark brown (10YR 3/3); friable; sandy loam; sticky and plastic; weakly developed medium nut and block structure; many roots; distinct undulating boundary.
Cu	on	Olive to yellowish brown (2.5Y 5/3-4/3); loose; sand; non sticky and non plastic; single grain structure; common roots.

Range of profile features (# of observations -)

May include buried A horizons due to localised blowouts. AC horizon may or may not be present.

Similar soils and distinguishing features

SPC-B	Has Bw horizon, characterised by change in colour.
SPC-M	Has Bw and BC horizons, the Bw identified by the presence of structure, the BC by colour different to that of the C horizon.
SPC-V	Is not as well developed, the topsoil lacks any real structure and is only up to 4cm thick.

Chemical data

pH	Strongly to moderately acid.
C%	Medium
N%	Medium
C/N ratio	Very low
inorganic P	Very high
organic P	Very high to medium

Limitations and potentials for use

Pasture;	Limitations of insufficient moisture.
Cropping;	Soils of hilly and steep land with very severe limitations to crop production - unsuitable.
Horticultural;	Soils of hilly and steep land with very severe soil limitations to horticultural use - not suitable.
Forestry;	Limitations of insufficient moisture.
Urban;	Soils of hilly and steep land with severe limitations to urban use. (Limitations are mainly of slope and erosion.)
Value for food production;	Soils of moderate actual or potential value for food production.

Land use ratings

Pasture;	5A
Cropping;	4
Horticultural;	4
Forestry;	2B
Urban;	5
Value;	2