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Land Use Capability Classification and Land Resources of the Bay of Plenty-Volcanic Plateau Region

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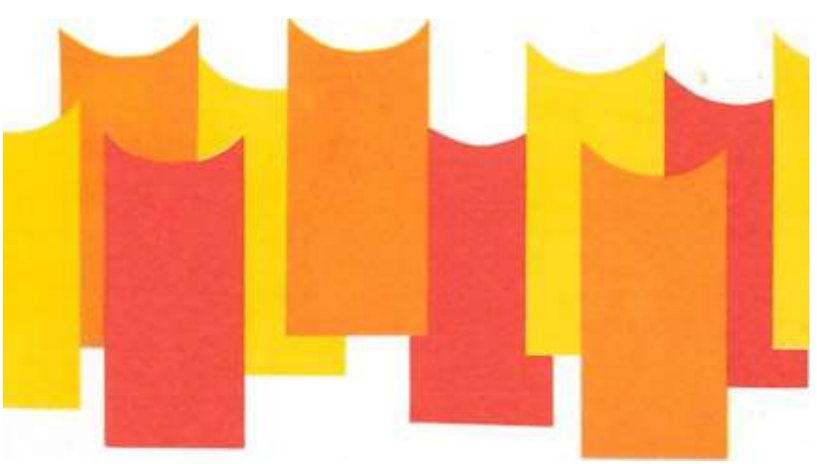

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Land Use Capability Classification and Land Resources of the Bay of Plenty—Volcanic Plateau Region: a bulletin to accompany New Zealand Land Resource Inventory Worksheets

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WELLINGTON 1985

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This bulletin describes the land use capability classification and land resources of the Bay of Plenty-Volcanic Plateau Region, an area of 17,800 km^2in the central North Island, New Zealand. This region is one of eleven mapped during the New Zealand Land Resources Inventory (NZLRI) survey by the Water and Soil Directorate of the Ministry of Works and Development for the National Water and Soil Conservation Authority. The NZLRI provides a physical land resources inventory and a land use capability (LUC) assessment at a scale of 1:63,360 (1 inch to 1 mile).

In the LUC classification of the region, 110 LUC units are recognised: these are arranged into 22 groups of related LUC units (known as LUC suites or subsuites). In this region, soil parent material has been the main criterion used to group LUC units. These soil parent materials are derived mainly from a number of Pleistocene and Holocene volcanic deposits which occur at or near the surface over most of the region and dominate many of the landforms. Within LUC suites and subsuites, LUC units are separated mainly according to relief, although climate, altitude and underlying rock type are also criteria used.

The bulletin provides a detailed description of each LUC suite and subsuite, covering its climate, physiography, rock types and soil parent materials, soils, erosion, agricultural and forestry productivity, present and potential land use and land management. The LUC units within each LUC suite and subsuite are described and illustrated with tables and photographs. Also included are a general regional description, a summary of physical resource factors and a discussion of land use over the whole region.

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CONTENTS

CHAPTER 1: INTRODUCTION

This bulletin is one of a series accompanying the New Zealand Land Resource Inventory (NZLRI). The NZLRI provides a unified coverage of physical land resource information for New Zealand, for the purposes of land resource and land use planning. The information is published as a series of Land Resource Inventory Worksheets at a scale of 1:63,360 (1 inch to 1 mile) (NWASCO 1975-79) together with supporting documents. It is also available as a computer data base using the retrieval program LADEDA (van Berkel & Eyles 1981). The survey has been carried out on behalf of the National Water and Soil Conservation Authority by the Land Resources Group of the Water and Soil Directorate of the Ministry of Works and Development, based at science centres in Palmerston North and Christchurch.

Two sets of data are shown on Land Resource Inventory Worksheets:

1) An inventory of five physical factors (rock type, soil, slope, erosion type and severity, and vegetation) which are basic to the assessment of land resources.
2) An assessment of the long-term potential for sustained production, in the form of a land use capability classification.

Further information on the methods of mapping and assessment, interpretation and application of the NZLRI are found in the "Land Use Capability Survey Handbook" (Soil Conservation and Rivers Control Council 1969) and in "Our Land Resources" (NWASCO 1979).

For the NZLRI the North Island was divided into ten survey regions, each with its own land use capability classification. Accompanying the Land Resource Inventory Worksheets for each region is an extended legend to the land use capability units of that region. A correlation of land use capability units in all ten North Island NZLRI regions has recently been prepared (Page 1985) (Appendix 2).

The Bay of Plenty-Volcanic Plateau Region is one of the ten North Island NZLRI regions*, in which preparation of NZLRI worksheets began in 1977 after preliminary work on the classification in the previous two years. All worksheets for the region were published in 1978 and 1979.

A total of eight scientists participated in the preparation of worksheets in the region. Figure 1 shows the boundaries and numbers of worksheets, while Appendix 1 lists the worksheets, their authors and dates of field work. Field checking and correlation of all worksheets in the region was carried out by K W Steel, regional supervisor, and G O Eyles, the group leader and North Island correlator. The regional LUC classification and extended legend were prepared by K W Steel (now Senior Soil Conservator, Ministry of Works and Development, Hamilton).

The principal aim of this bulletin is to explain the basis of the land use capabilility classification adopted for this region and to describe the land use capability units delineated. It supplements the extended legend for the region (Steel 1979) which summarises much of the resource information for each land use capability unit. This bulletin places more emphasis on explaining relationships between different land use capability units, and special features of the classification which could not be easily summarised in the extended legend format. To show the relationship between land use capability units, the concept of groups of related units (called suites) has proved to be very useful and has been given special emphasis in this bulletin (see Chapter 5). Present and potential land use for each group of land use capability units has also been emphasised.

The main part of the bulletin is a detailed description of each land use capability suite and its constituent land use capability units, dealing with physical factors, land use, and land use capability (Chapter 5). This is preceded by a description of the region and a summary of its physical resource factors as they relate to the NZLRI (Chapters 2 and 3). The bulletin is not intended to be an exhaustive resource document for the region, although it does aim to refer the interested user to some of the more detailed literature available, especially on

♦Throughout this bulletin the term region is used in this sense unless specifically stated otherwise.

geological and soil resources. Compared with many other parts of New Zealand, there is considerable published and unpublished material relevant to land resources and land use capability in this region, but it is rather scattered. Emphasis is given here to the more recent literature, because an early volume of the National Resources Survey (1962) provides a comprehensive survey of the region at that time.

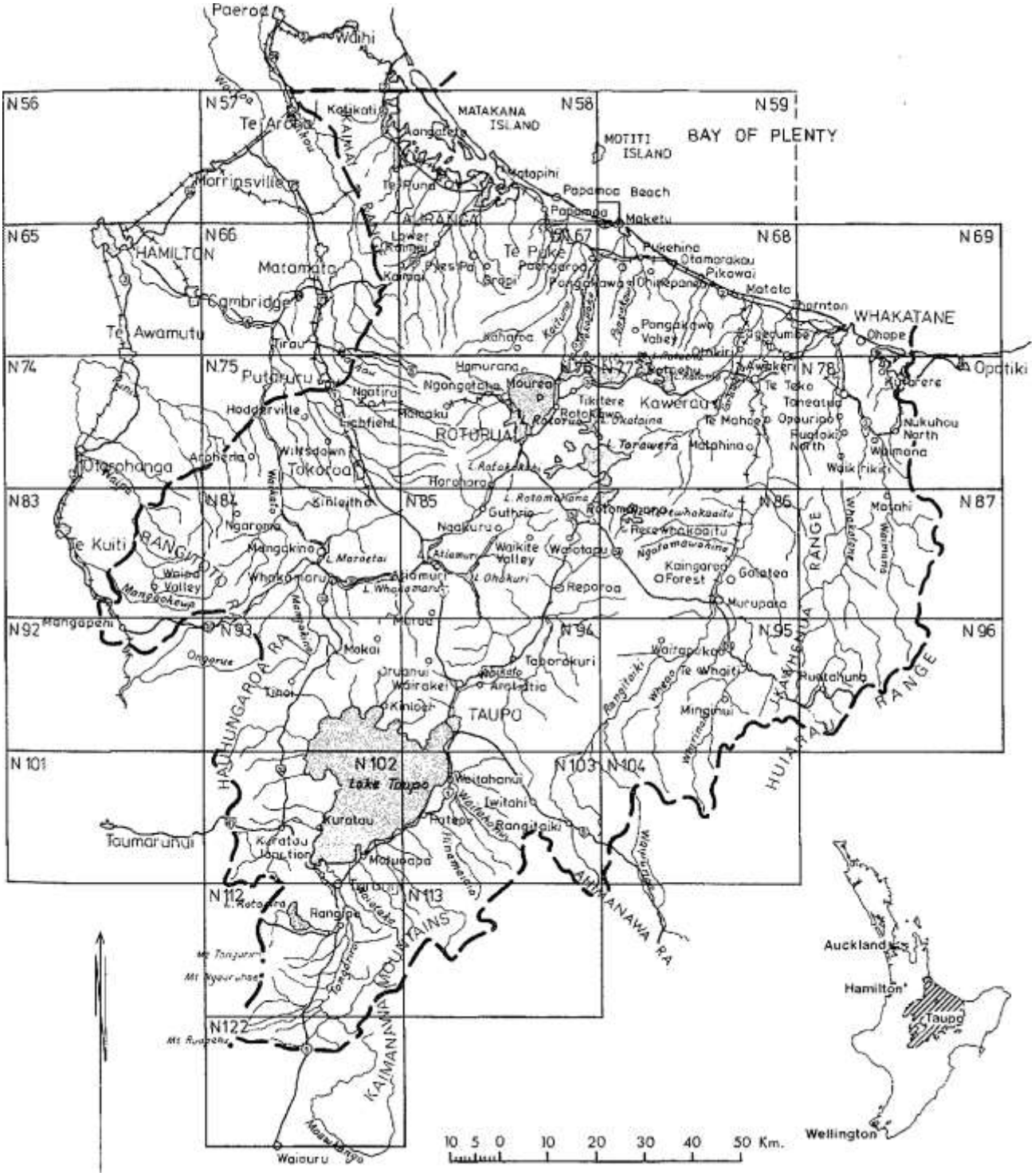

Fig. 1: Location and main physical features of the Bay of Plenty-Volcanic Plateau Region. Grid shows position of NZLRI worksheets. (Worksheet numbers and boundaries coincide with NZMS1 topographical maps which were used as worksheet bases). Regional boundary is shown as heavy dashed line.

CHAPTER 2: DESCRIPTION OF THE BAY OF PLENTY-VOLCANIC PLATEAU REGION

Location and Boundaries

The Bay of Plenty-Volcanic Plateau Region, as delineated in the NZLRI, has an area of 17 810 km^2, extending from the Bay of Plenty coastline towards the centre of the North Island (Fig. 1). The regional name is an amalgamation of the popular geographical terms Bay of Plenty (in a narrow sense the coastal district only, but often used to describe the entire volcanic district as far south as Lake Taupo) and Volcanic Plateau (usually referring to the elevated volcanic district south of Lake Taupo).

The region is bounded to the north by the northern margin of NZMS1 N57 and N58, slightly north of Katikati and Te Aroha. The western boundary is defined by the western edge of the Kaimai Range and then turns south-west across the southern Waikato basin as far as Benneydale. From here the region is defined on a catchment basis. The boundary follows the western and southern boundary of the Lake Taupo catchment and then continues to the north-east along the main divide between catchments draining into Hawke's Bay and Bay of Plenty. The boundary then heads north following the divide between the Waimana and Waioeka catchments, reaching the Bay of Plenty coast on the Ohiwa Harbour.

Physical Features

Important physical features of the region are shown in Fig. 1. The main ranges and mountains lie on the edges of the region, namely the Kaimai Range in the north-west, the Rangitoto and Hauhungaroa Ranges in the west, the volcanoes of Tongariro National Park in the south, the Kaimanawa Range in the south-east, and the various ranges of the Ureweras to the east. The region rises from sea level along the Bay of Plenty coastline towards the south, where it attains an altitude of 2751 m a.s.l. on Mt Ruapehu. Most of the surrounding ranges have crests at between 900-1500 m a.s.l. In addition to these there are several elevated plateaux, smaller ranges and isolated volcanic peaks in the interior of the region.

Lakes are a prominent feature of the natural landscape, including Lake Taupo, the largest in New Zealand (606 km^2) (Forsyth & Howard-Williams 1983), as well as many smaller lakes, mostly within the so-called Rotorua Lakes District (Chapman 1980). The major river is the Waikato River, longest in the North Island, which flows first north-east from Lake Taupo, then north-west, leaving the region at Arapuni. All other major rivers flow into the Bay of Plenty (e.g., Waimana, Whakatane, Rangitaiki, Tarawera, Kaituna and Wairoa Rivers), or into Lake Taupo (e.g., Tongariro and Waihaha Rivers).

Physiography

Major physiographic features of the region are described in notes on the relevant sheets of the NZ Geological Survey 1:250,000 Geological Map of New Zealand series. An excellent account of the physiography and landforms of most of the region is given by Healy (1982), upon which much of this section has been based. Almost all of the region falls within an area named by Healy as the Central Volcanic Region, which is dominated by volcanic landforms developed only during the last one million years. Volcanism continues to affect the landscape in the form of volcanic eruptions, lahars, earthquakes, and geothermal activity. Volcanic rocks overlie an older sedimentary basement which borders much of the region and also outcrops in places within the volcanic terrain.

Within the Central Volcanic Region, three broad zones can be clearly distinguished (generally aligned in a south-west to north-east direction), while three smaller zones occur outside it, giving six major physiographic zones in the NZLRI region (Fig. 2).

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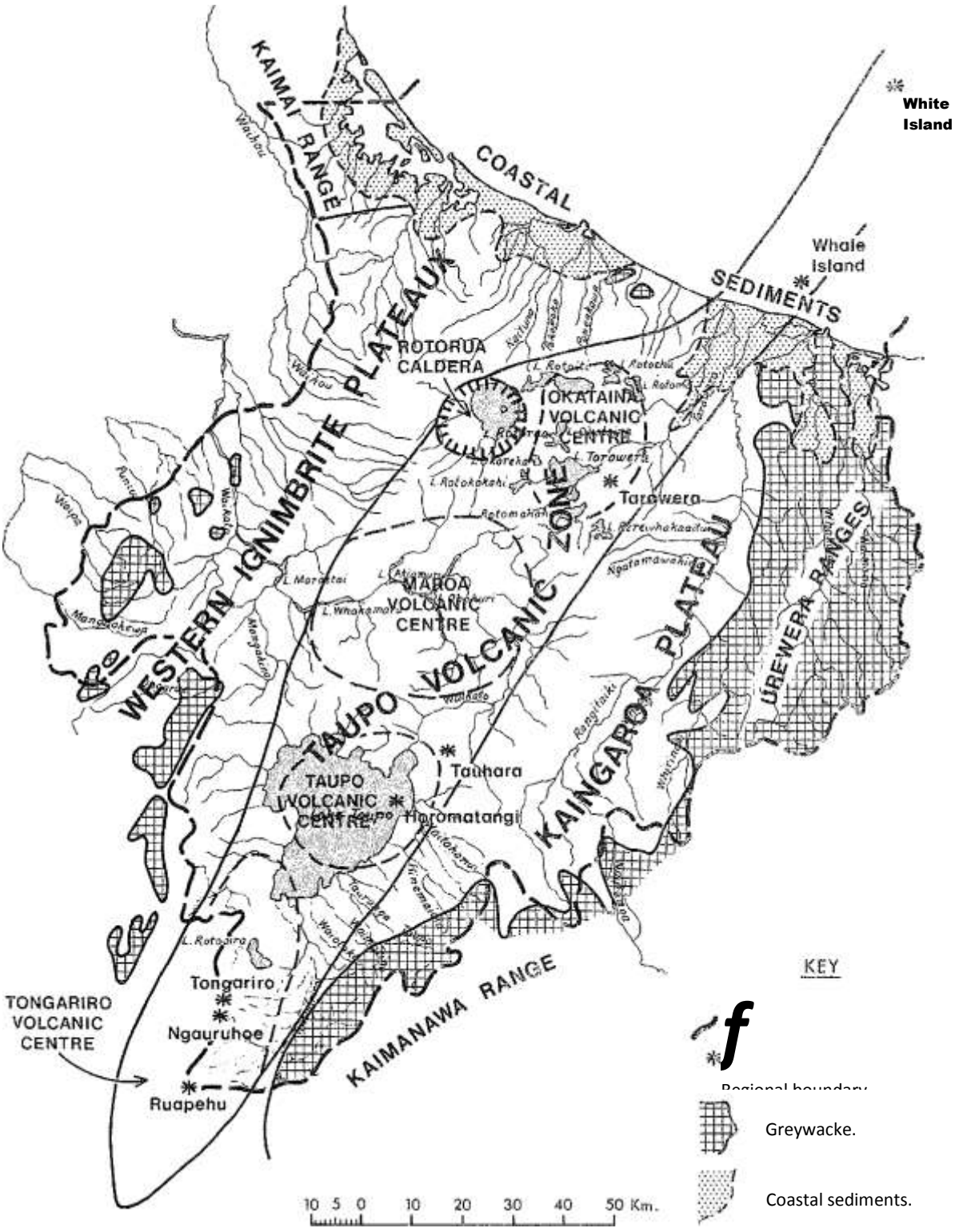


Fig. 2: Major physiographic zones in the Bay of Plenty-Volcanic Plateau **Region. Modified** from **Healy (1982). The unshaded portion forms Healy's "Central Volcanic Region".**

1) Kaingaroa Plateau: A series of three ignimbrite plateaux occurs in the east of the Central Volcanic Region from Te Teko to eastern Lake Taupo, mostly at an altitude of 550-600 m a.s.l. They are remarkably flat, forming one structural unit known as the Kaingaroa Plateau.

2) Western ignimbrite plateaux: A further series of ignimbrite plateaux occur in the west of the Central Volcanic Region, between the Bay of Plenty coastline and the western edge of Lake Taupo (altitude 357 m a.s.l.). The ignimbrite surfaces show a considerable variation in age and degree of dissection. They are underlain by greywacke, which outcrops at several places.

3) Taupo Volcanic Zone: A central unit which contains all the recent eruptive centres of the Central Volcanic Region. Volcanism, faulting and subsidence have contributed to an enormous variety of topography and constructional forms as well as other features such as grabens, calderas, lakes, scarps, etc.

4) Kaimanawa and Urewera Ranges: The largest zone occurring outside the Central Volcanic Region consists of the eastern and south-eastern ranges of Mesozoic rocks. The Kaimanawa Range and, within the Ureweras, the Huiarau Range represent part of the axial ranges of New Zealand, while the other Urewera ranges are north-south aligned outliers. These ranges are bounded and broken by major faults, through some of which flow rivers such as the Whakatane and Waimana.

5) Kaimai Range: The Kaimai Range, composed of Tertiary volcanic rocks, joins onto the north-west end of the western ignimbrite plateaux, thus forming a continuous barrier between the Bay of Plenty and the Waikato lowlands.

6) Coastal sediments: Along the Bay of Plenty, coastal sediments lap onto all the previously described regions and partially fill sedimentary tectonic basins in the Tauranga, Maketu and Opotiki areas. The coastal fringe itself is sandy, interrupted by only a few promontories of older sedimentary rocks and one rhyolitic dome.

All six zones can be subdivided into numerous constituent landform units. This is not done in this chapter although many will be mentioned in Chapter 5. The following briefly describes some important features and processes common to the Central Volcanic Region (see Chapter 3 for further notes on geological terms):

a) Ignimbrites of various kinds are probably the most dominant feature of the landforms of the region. There were several phases of ignimbrite eruption, which are reflected in the comtemporary relief pattern; for example, older areas in the west, between the Rangitoto Range and the Waikato Basin, are extremely dissected, whereas younger plateaux such as the Mamaku Plateau still largely retain their original form.

b) Other 'hard' volcanic rocks include viscous rhyolitic lava flows forming steep sided domes, which are a characteristic landform unit in and at the margins of the volcanic centres, and which may rise to a considerable height, e.g., Mt Tarawera. Andesite forms the still higher stratovolcanoes of the Tongariro Volcanic Centre (Gregg 1960) which are aligned in a north-east to south-west direction. Some of these mountains, e.g., Ruapehu, are surrounded by plains of laharic deposits.

c) Breccias, which may be described as unwelded ignimbrites ***{'nuees ardentes'),*** are another important volcanic unit. They also form plateaux, e.g., east and north of Lake Taupo and the Kaharoa Plateau, but because of their unconsolidated nature these are more dissected than 'hard' ignimbrites. They are an important source of tephric alluvium and in the past have created lakes by blocking valleys. Recent ***nuees ardentes*** can also be described as unwelded ignimbrites, e.g., Taupo flow tephra (Froggatt 1981).

d) Calderas are large depressions formed from the collapse of magma chambers following major ignimbrite eruptions. They are common in the Taupo Volcanic Zone; many of the lakes in the Rotorua district, as well as the western bay of Lake Taupo, occur within them.

e) Tectonism has affected the zone widely. Several major faults along which geothermal activity occurs pass through the region, and boundaries between physiographic zones are often located along these faults. The major axis of faulting is south-west to north-east. There are several tectonic basins and other physiographic features which are structurally controlled, e.g., Galatea Basin, Whakatane Graben, etc.

f) Tephra eruptions of the last 20,000 years, as well as those accompanying the previous breccias and ignimbrites, have mantled the whole of the region and have had the overall effect of evening out the relief, but the effect of this is continually modified by erosion. This latter process has resulted in alluvial or lacustrine redeposition in grabens, fans, basins and terraces, of which the largest expression is the lower Rangitaiki Plains in the Whakatane Graben. The genesis of these depositional landforms has been studied in a series of papers by W A Pullar and co-workers, who have described the history and past environments of the various areas by interpretation of the dated sequence of tephra deposits (Pullar ***et al.*** 1968; Pain & Pullar 1968, 1975; Pullar & Selby 1971; Kennedy ***et al.*** 1978).

Hydrology

Hydrological features of the region are summarised by Freestone (1974) and are also discussed by Selby (1972, 1973), Selby & Hosking (1973), and Jackson (1974). These authors specifically refer to areas with yellow-brown pumice soils but their comments are also relevant to areas of other volcanic soils in the region.

The most significant hydrological characteristics in the region include the prevalence of deep groundwater springs, many dry headwater channels (i.e., ephemeral stream channels suffering a severe water deficit in the upper catchment region), very steady base flows, and high soil infiltration rates and ground water storage capacity, with subsequent comparatively low flood discharges. However, the effects of change in land use on runoff rates have in some cases been spectacular. This may be in the direction of greatly increased runoff due to soil compaction after conversion from woody vegetation to pasture (Selby 1972), or greatly reduced runoff after conversion from pasture to exotic forest (Dons 1981). The relationships between runoff and erosion have been discussed by Selby (1972), Selby & Hosking (1973), and Healy (1967). A very large recorded increase in flood flows of the mid-Waikato River between 1950 and the late 1960s is attributed largely to agricultural development involving conversion of scrub to pasture in the contributing catchments (Jellyman 1973).

Water quality in the region also shows widely varying response to land use. McColl & Hughes (1981) reviewed this subject for New Zealand generally, including unpublished material from the Bay of Plenty-Volcanic Plateau region. Hydrology and water quality of the Lake Taupo catchment is summarised in Schouten ***et al.*** (1981), and Forsyth & Howard-Williams (1983). Lakes are particularly sensitive to increased levels of suspended sediment and nutrients which are most likely to arise from agricultural topdressing (McColl & Hughes 1981). Research in progress at Taupo (Division of Marine and Freshwater Science, DSIR) has shown that wetland communities in streams draining the area effectively remove nutrients from groundwater drained from pasture. However, long-term trends are very difficult to assess, as reviewed by Biggs (1980) for Lake Rotorua where urban population is also a significant factor in water quality. Nutrient concentrations in the lake waters are generally moderate to high but no overall change in lake condition indicators has been documented in spite of significant short-term fluctuations.

Cultural Features

The main settlements in the region are shown in Fig. 1. The two largest urban areas are Tauranga (1981 population 53,000 including Mt Maunganui Borough) and Rotorua (48,300 including Ngongotaha Borough). Other major urban areas are Tokoroa (19,300), Taupo (15,400) and Whakatane (15,200), while other town boroughs are Kawerau, Te Puke and Murupara.

A railway line serves the northern Bay of Plenty, entering through the Kaimai Range and running via Tauranga, Whakatane, and Kawerau to Murupara. Rotorua and Tokoroa are also joined by rail to the Waikato Basin. Three major highways run through the region: SHI from Waiouru through Turangi, Taupo, Tokoroa and Putaruru; SH2 from Katikati through Tauranga, Whakatane and Opotiki; and SH5 from Rangitaiki through Taupo and Rotorua to Tirau. Several provincial highways run through the region and there is a network of county and forestry roads. Regular air services run from Tauranga, Whakatane, Rotorua

and Taupo. There is only one major port, at Mount Maunganui, but because of large volumes of forestry exports, this is the second largest in the country in terms of tonnage.

Administratively, the region is divided into four main counties and districts (Tauranga, Rotorua, Taupo and Whakatane), as well as smaller areas of five other counties, and the urban areas mentioned above. For water and soil conservation purposes, there are three catchment authorities which operate within the region: the Bay of Plenty Catchment Commission (headquarters at Whakatane); the Waikato Valley Authority (headquarters at Hamilton); and the Hauraki Catchment board (headquarters at Te Aroha).

Past and Present Land Use

History of land settlement: Before European colonisation, many parts of the region were intensively used for agriculture and hunting by Maoris, resulting in considerable modification of the primitive vegetation cover, both in pre-European and early European times (see p. 28). Early travellers commented on the scrub and fern cover over many parts of the region. European settlement and farming commenced in the 1890s, with extensive holdings in the Galatea basin and smaller ones in the Tauranga-Katikati district, usually associated with milling of native timber. Early expansion was slow due to soil fertility problems (e.g., 'bush sickness') and to the difficulty of draining potentially fertile swamp areas. However, in the period 1920-1940 more extensive agricultural development took place, led by state land development schemes in the southern Rotorua district (Department of Lands 6k Survey 1975). In the mid 1930s 'bush sickness' was identified as a cobalt deficiency and control measures introduced, so that by 1939 about 8000 ha of pumice soils were being farmed. The interwar period also saw a major part of the exotic forest plantation established, based initially at Whakarewarewa, on the Kaingaroa Plateau and in the Tokoroa-Atiamuri district (Boyd 1980).

After 1945 there was a further increase in indigenous forest clearance and land development for exotic forestry and for pastoral farming, the latter especially in the Taupo district. Sheep farming became the predominant agricultural activity. There was an intensification of agricultural use on the coastal plains following better flood control and drainage.

Significant trends in the last 15 years include further major agricultural land development, the decline of indigenous forest logging to a minor land use, a second major phase of expansion in exotic forestry, especially around the Taupo basin, and a major expansion of horticulture in the Bay of Plenty which has displaced some of the dairy industry.

Present land use pattern: The present land use pattern can be summarised under the categories of pastoral farming, arable farming, forestry and undeveloped land.

Pastoral farming occupies just over 30% of the region and is based on cattle and sheep rearing; fattening is concentrated in lowland areas, while breeding occurs on steeper hill country and at higher altitudes. Dairying, which occupies just under one third of the pastoral area, is also concentrated in lowland districts. Supplementary fodder cropping or lucerne production are important in pastoral farming systems away from the Bay of Plenty lowlands. The main pasture species of cultivated or oversown pastures are relatively high-producing ryegrass and clover varieties. Deer farming has become increasingly important, especially in wetter districts, while goat farming is also becoming firmly established. There are three large dairy factories and one mutton and beef meat works within the region.

Despite its economic importance in the region, intensive arable farming occupies less than 4% of the total area. (Historically the area and type of arable farming has fluctuated considerably.) This includes supplementary feed cropping which is the largest and most widespread arable use. Maize and lucerne are extensively grown as both cash and feed crops, lucerne also becoming an increasingly important pasture crop. Horticulture is now a major and still increasing land use in the Bay of Plenty. The main orchard crops are kiwifruit and citrus fruits but other subtropical tree and vine crops such as tamarillo, avocado, feijoa and passionfruit are increasing in importance. Pip and berry fruits are of lesser importance. Market gardening is rapidly increasing and diversifying, especially on the Rangitaiki Plains, and also around Rotorua where thermally heated greenhouse crops are significant.

Exotic forestry occupies more than 25% of the region. The industry is based on radiata pine with smaller areas of douglas fir and eucalypts. Exotic forestry is being increasingly practised on a farm woodlot scale and in combination with grazing regimes (agroforestry) (Percival ***et al.*** 1983). Indigenous forestry has been a major factor in the development of much of the region, but is now a minor land use.

Undeveloped land occupies approximately 40% of the total area of the region. The major portion of this is forested ranges whose main function is watershed protection. Indigenous forest (often cutover) and forest-scrub mixtures occur on hill country and lowland steepland areas, but compared to many other parts of the country the region has a small proportion of scrub-covered or partially developed agricultural land. Most scrub which occurs on extensively used agricultural land and undeveloped land is mixed indigenous scrub or bracken fern. The most significant exotic scrubweeds are gorse, broom, lupin, Spanish heath and blackberry, but all are locally significant rather than widespread. Other undeveloped areas include wetlands, coastal sand-dune and tidal systems, and subalpine heathland, tussockland and scrubland around the Tongariro Volcanic Centre. Undeveloped land and some of the exotic forest areas are extensively used for recreation and many of the remaining areas of indigenous vegetation have high value for flora and fauna conservation (Imboden 1978, Saunders 1983). There are portions of two National Parks and four State Forest Parks within the region, as well as many scenic reserves.

More information on land use is given in Chapter 5, while future trends are briefly discussed in Chapter 6. Sources of data on land use are computer summaries of NZLRI .data, National Resources Survey (1962), and information from the Aglink series of Ministry of Agriculture and Fisheries. A study of land potential in the region (NWASCO 1982), which used the NZLRI as its information base, has also been extensively used. This latter publication presents information on present and recommended future land uses and the economic returns, costs, associated off-site benefits and soil conservation measures for various land uses.

CHAPTER 3: PHYSICAL RESOURCE FACTORS IN THE REGION

INTRODUCTION

The physical resource inventory component of the NZLRI is recorded in the form of a standard code for each map unit, which contains information on five physical factors. These are rock type, soil unit, slope, erosion severity and type, and vegetation cover. The standard layout of the inventory code is:

Rock type—Soil unit—Slope group

Erosion severity and type—Vegetation cover

These inventory factors, together with climate and the effects of past land use, provide the basis for determining the land use capability of each map unit. In the homogeneous unit area approach to mapping, as used in the NZLRI (Eyles 1977), the five factors in the inventory code are recorded together in each map unit (within the limitations of scale). The median map unit area for the Bay of Plenty-Volcanic Plateau Region is 126 ha, although map units down to a minimum size of approximately 20 ha are recorded.

This chapter provides a summary of the physical resource factors of the region, as mapped in the NZLRI. It also includes notes on climate, and a brief description of the method of mapping each inventory factor. These summaries refer to the region as a whole; more details on the physical resource factors of individual LUC units are given in Chapter 5.

CLIMATE

This resource factor is not recorded on the NZLRI worksheets but was an important factor in assessing the land use capability of any given area. Sources used for this assessment were the 1:500,000 isohyet map of New Zealand (NZ Meteorological Service 1978), records of rainfall normals (NZ Meteorological Service 1973) and climatological records from individual stations (NZ Meteorological Service 1983a). Climatological stations located in the region are shown in Fig. 3a. The climate and weather of the region were described by de Lisle (1962)*.

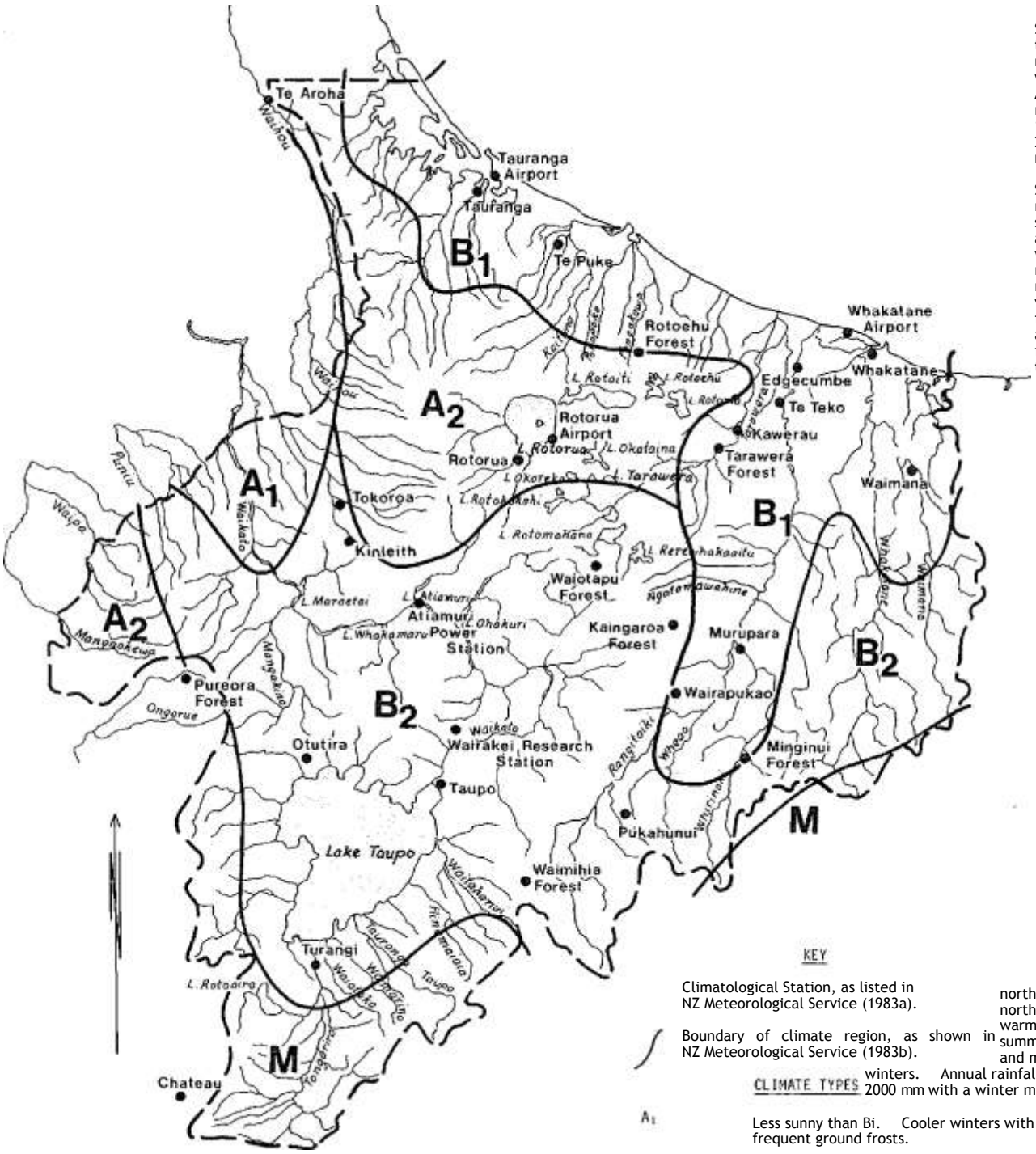
Two significant factors influencing the climate of the region as a whole are as follows:

a) The region is relatively sheltered from New Zealand's prevailing westerly winds by the almost continuous barrier of mountain ranges and upland areas along its western borders. The region is therefore relatively calm. Its northern part is strongly influenced by weather from the north and north-east, which is more tropical and cyclonic in nature.

b) The location of the region suggests a generally warm temperate temperature regime. However, the many upland areas and great range of altitude from sea level to the highest point in the North Island, result in considerable temperature variations.

The climatic regions of the Bay of Plenty-Volcanic Plateau, as defined in NZ Meteorological Service (1983b) (Fig. 3a), are mainly of types A and B, with warm summers, mild winters and between 1000-2500 mm annual rainfall. Remaining areas of the region have a mountain climate (type M), with higher rainfall, more wind and variable but generally cooler temperatures. Note that Fig. 3a is a generalised and small-scale excerpt from a map showing national patterns. It does not identify all the significant regional aspects of climate; for example, no distinction is made between coastal and inland parts of region B„ between lowland and cooler upland parts of region A_2, and of those parts of region B_2that are subject to very dry summers.

***An updated account has recently been published (Quayle 1984) which includes data on derived parameters such as soil water balance, degree-day totals, vapour pressure and humidity.**



KEY

Climatological Station, as listed in NZ Meteorological Service (1983a).

Boundary of climate region, as shown in NZ Meteorological Service (1983b).

CLIMATE TYPES

A1

Less sunny than Bi. Cooler winters with frequent ground frosts.

High rainfall mountain climates. Conditions vary greatly with altitude and exposure.

Similar to Ai but much wetter. Annual rainfall 1500 to 2500 mm.

Sunny rather sheltered areas which receive rains of very high intensity at times from the northeast and north. Very warm summers and mild winters. Annual rainfall 1000 to 2000 mm with a winter maximum.

Warm humid summers, mild winters. Annual rainfall 1000 to 1500 mm with a winter maximum. Prevailing wind southwest but occasional strong gales and heavy rains from the east or northeast from Hamilton northwards.

10 5 0 10 20 40 50 Km.

30

Fig. 3a: **Climatic regions of the Bay of Plenty-Volcanic Plateau Region (from NZ Meteorological Service 1983b), and location of climatological stations within and adjacent to the region.**

Rainfall: Total annual rainfall over the region is relatively high by New Zealand standards: rainfall does not regularly fall below about 1000 mm annually, and much of the region receives 1400-2000 mm. However, the number of rain days per annum is not high, indicating that much rain occurs in heavy falls associated with tropical depressions approaching from the east or north-east. 24 and 48-hour rainfall maxima are relatively high. These falls can occur at any time of the year. However, monthly rainfall totals are generally highest in late autumn and winter. Summer moisture deficits which are agriculturally highly significant occur over most of the region, and are particularly severe in the Taupo-Wairakei area and in coastal Bay of Plenty (Fig. 3b).

Temperatures: Temperatures are broadly related to latitude but are generally warm north of Lake Taupo. The most consistently warm part of the region is eastern coastal Bay of Plenty. Warm summer temperatures experienced over most of the region exacerbate moisture deficits. Few areas in the region are, however, free of minor ground frosts although they are rare in summer in the Bay of Plenty. The coldest areas are the Kaingaroa Plateau and the Volcanic Plateau (Fig. 3c), which may experience screen frosts at any time of the year

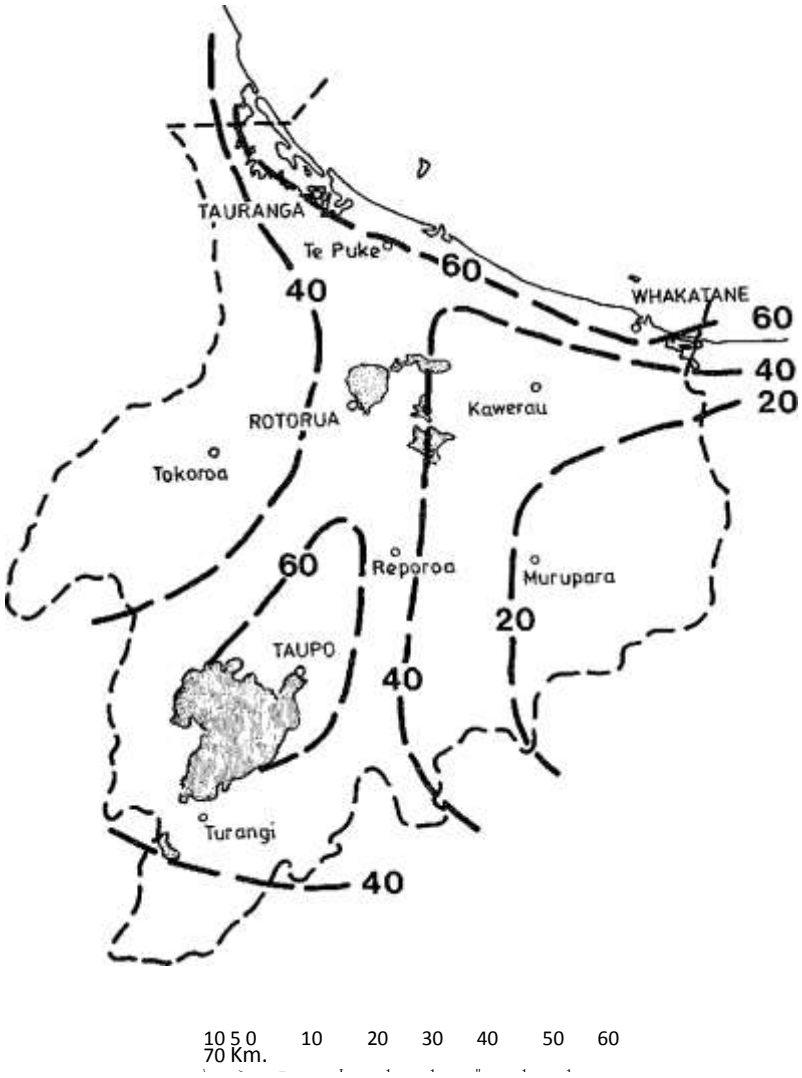


Fig. 3b: Average percentage of the growing season during which deficient monthly rainfalls result in soil moisture reserves being depleted by more than 8cm (from de Lisle 1962).

and do so consistently during winter.

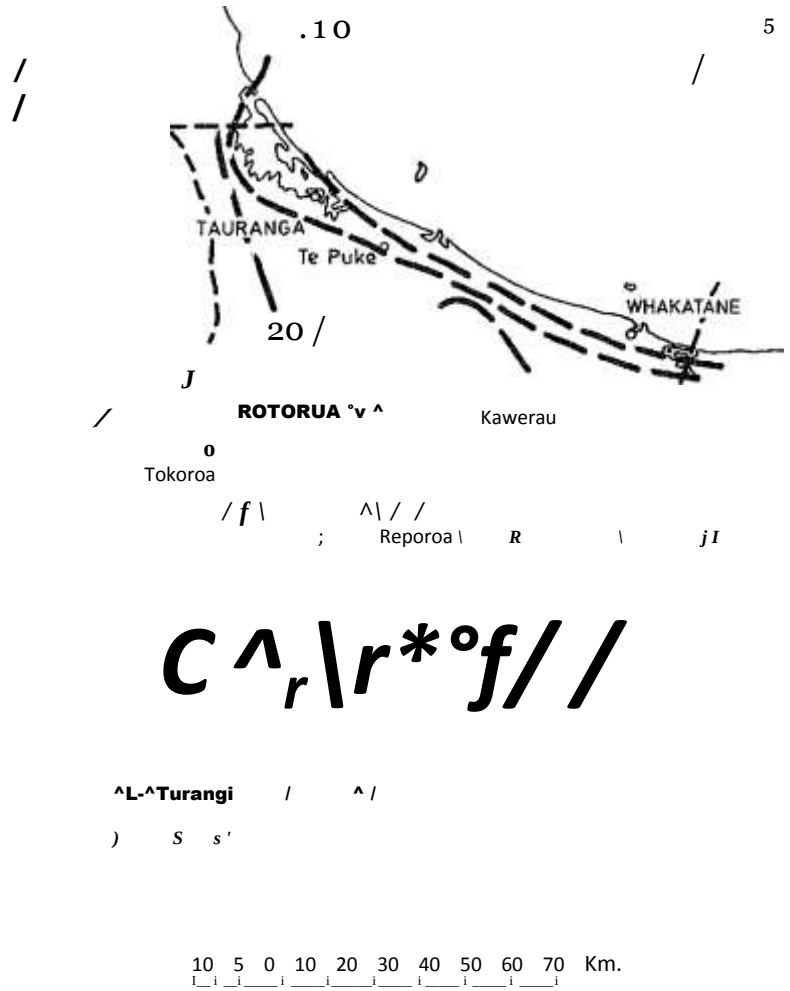


Fig. 3c: Average number of screen frosts per year (from de Lisle 1962).

Wind: Data on wind in the region are generally scarce, being recorded at only nine stations, usually airports. Much of the region is sheltered from prevailing westerlies and south westerlies: areas near sea level are some of the least windy districts in New Zealand. Elevated areas, especially in the west and south of the region, and coastal areas, are thought to be much more windy, although quantitative data are meagre. Spring and summer are the windiest seasons, but not markedly so.

Other Climatic Elements: Cloud cover in the Bay of Plenty is relatively light and the coastal Bay of Plenty is very sunny with low humidity. Humidity levels in other districts are comparable to other North Island districts. Thunderstorms occur relatively frequently, especially around the Kaimai Range and northern Bay of Plenty. Fog is common in winter in low-lying areas between Taupo and Rotorua, along the Waikato River and river valleys in the Urewera ranges, and in some upland areas, especially the Kaimai Range (Jane & Green 1984). Snow is common on the Volcanic Plateau in the winter, and can fall on the higher mountains at any time of the year. Significant hailstorms may be associated with cyclonic events in coastal areas.

ROCK TYPES AND SOIL PARENT MATERIAL

Rock Type Mapping: Rock types were recorded for each map unit, using the NZLRI North Island rock type classification (Crippen & Eyles 1985). This classification, designed specifically for soil conservation purposes, groups together rocks and lithological types with similar erosion susceptibilities.

Basic geological information was obtained from the NZ Geological Survey 1:250,000 Geological Map of New Zealand series. Most of the region is covered by Sheet 5 Rotorua (Healy ***et al.*** 1964b) and Sheet 8 Taupo (Grindley 1960) of this series, with smaller remaining areas covered by Sheet 4 Hamilton (Kear 1960) and Sheet 7 Taranaki (Hay 1967). Two 1:63,360 geological maps were also used: these covered NZMS1 sheets N85 Waiotapu (Grindley 1959) and N94 Taupo (Grindley 1961). However, these maps do not generally show surficial deposits, which over much of the region are very often important soil parent materials. For the mapping of these, many sources from the published geological literature were also consulted (see Table 2) and supplemented by extensive field observation.

TABLE 1: NZLRI rock types recorded in Bay of Plenty-Volcanic Plateau Region.

Rock type	*NZLRI mapping symbol*	*Typical formations in 1:250,000 Geological Map of NZ*	*% of region mainrock*[1]	*midrock*[2]	*toprock*[1]
Breccias older than Taupo	**Ft**	**Rotoiti Breccia**	**8.7**	**0.6**	**0.1**
		Oruanui Breccia			
'Hard' volcanic rocks	**Vo**	**Whakamaru Ignimbrite**	**37.0**	+	— —
		Haparangi Rhyolite			
Unconsolidated to	**Us**	**Huka Group**	**5.7**	+	–
moderately consolidated		**Hinuera Formation**			
sediments					
Massive mudstone or fine siltstone	**Mm"**		**0.2**	—	—
Banded mudstone or fine siltstone	**Mb**	**> Southland Series**	+	—	—
Jointed mudstone or fine siltstone	**Mj.**		+	—	—
Massive sandstone or coarse siltstone	**Sm**	**Southland Series**	**0.6**	—	—
		Ohakuri Group			
Banded sandstone or coarse siltstone	**Sb**	**Southland Series**	**0.1**	—	—
Greywacke	**Gw**	**Urewera Greywacke**	**16.2**	—	— —
		Kawhia Series			
Ngauruhoe ash	**Ng**	**Ngauruhoe Formation**	—	—	**1.6**
Tarawera Ash and Lapilli	**Ta**	**Tarawera Formation**	+	—	**4.5 •**
Rotomahana Mud	**Rm**	**Tarawera Formation**	+	—	**0.8**
Kaharoa and Taupo ashes	**Kt**	**Taupo Sub-group**	+	**1.6**	**27.0**
Ashes older than Taupo	**Mo**	**Rotorua Sub-group**	**6.3**	**23.4**	**43.6**
Pumice		**Tongariro Sub-group**			
Lapilli	**Lp**	**Waimihia Formation**	**1.6**	**4.2**	**0.2**
		Mangaone Formation			
Taupo and Kaharoa flow	**Tp**	**Taupo Pumice Formation**	**16.2**	+	**0.6**
tephra and water-sorted					
tephra					
Lahar deposits	**La**	**Rangipo Lahar**	**0.7**	—	—
Peat	**Pt**	—	**0.5**	—	—
Windblown sands	**Wb**	—	**0.5**	—	—
Gravels	**Gr**	—	**0.2**	—	**0.1**
Undifferentiated floodplain	**Al**	—	**0.2**	—	—
alluvium					

Unmapped areas	—	—	**5.1**	—	—

Notes: Percentages rounded to nearest 0.1%.

+ indicates rock type recorded but covers < 0.05% of area of region.

1 % of area of region recorded as underlying, sole or dominant rock type.

2 % of area of region recorded as interlayer rock type in stratigraphic sequence.

3 % of area of region recorded as surficial rock type in stratigraphic sequence, including patchy surficial distribution.

NZLRI rock types recorded in the region are shown in Table 1, together with an indication of their relative areas as a percentage of the area of the region. In some cases the names of rock types used in Table 1 and throughout this bulletin differ slightly from names used in worksheet legends and in the NZLRI Rock Type Classification (Crippen & Eyles 1985). However, in all cases the symbols are the same and the rock types denoted are as described in the NZLRI Rock Type Classification. For each rock type, the area percentages are split into the three categories of main or underlying rock type, interbedded rock type, and surface rock type (abbreviated to mainrock, midrock, and toprock respectively in Table 1). The relationship between these categories in the field is shown in Fig. 4. The reason for this separation is that there is often a clear division between rocks which are important in the underlying geology, and rock types which are important in the surficial geology and which form the soil parent material. In the Bay of Plenty-Volcanic Plateau Region the latter are predominantly volcanic ejecta which mantle most of the area. They are of various depths and textures but are collectively known as tephras (Cole & Kohn 1972). It should be noted that because the NZLRI inventory only recognises rock types that directly influence surface morphology and land use, and because a maximum of three rock types in a stratigraphic sequence was recorded, the underlying or local basement rock type is often not recorded, especially on flat land. For example, Tp recorded as 'mainrock' in Table 1 indicates deep flow tephra or water-sorted tephra. Similarly, Mo is often the basal recorded rock type on flat to rolling land. In neither case does this imply that there is no underlying rock type. The following brief account of the rock types of the region maintains the separation between underlying and surface or interbedded rock types.

Taupo Pumice

Mo tephras

Ignimbrite:

Taupo flow tephra

NZLRI rock type inventory.

I

I (Kt)/Mo/

Vo Kt/Mo

Rock type category.

M I I Vo M S/ U

s / \ / *u*

Kt/Mo/V

o

S / l /

U

Fig. 4: Schematic representation of typical Bay of Plenty landscape showing relationship between rock types as recorded in NZLRI rock type inventories and in Table 1. M = main rock type ('mainrock' in Table 1), U = underlying rock type ('mainrock' in Table 1), I = interbedded rock type ('midrock' in Table 1), S = surface rock type ('toprock' in Table 1).

Underlying Rock Types: The underlying rock types were mainly those mapped in the NZGS 1:250,000 Geological Map series. Apart from the Kaimanawa and Urewera ranges they are mostly volcanic rocks less than 0.75 million years old (Healy 1982). The most extensive underlying rock type is 'hard' volcanic rock (Vo), of which the most extensive in turn is ignimbrite, a rhyolitic rock erupted in high temperature pyroclastic flows, forming extensive sheets. They are generally welded ('welded tuffs') but may be unwelded, especially in the upper portions.

Other rhyolitic rocks form domes or cones of various size (e.g., Maroa and Okataina Volcanic Centres, Mts Tarawera and Ngongotaha). Andesitic volcanoes of the Tongariro Volcanic Centre form an impressive feature of the southern part of the region. Other minor types of 'Vo' rocks in the region are dacites and basalts (e.g., Mt Tauhara, Karangahape).

Younger, 'softer', non-welded pyroclastic flows or breccias, mapped as Ft, (excluding Taupo flow tephra, see below) are important rock types in the region. The most significant are the Earthquake Flat and Rotoiti Breccias (Nairn & Kohn 1973), and Oruanui Breccia, now included within the Kawakawa Formation (Vucetich & Howorth 1976a) and correlated with the Waitahanui, Wairakei and Mihi Breccias of Grindley (1960). These most commonly overlie hard volcanic rock, but because of their thickness, where they occur they are most commonly recorded as the basal rock type in the inventory. A further group of volcanic materials consist of redeposited pumice breccias and tuffs interbedded with sandstones and siltstones (Ohakuri and Huka Groups). These have been variously classified as Us, Ft, Sm and Vo in the NZLRI rock type classification.

Non-volcanic underlying rocks are dominantly indurated sedimentary rocks mapped as greywacke, although they include a few schists and argillites in the middle Kaimanawa and Urewera ranges and some Tertiary sandstones and mudstones in the Urewera and Hauhungaroa ranges. Greywacke underlies most of the region (see cross sections on T.250,000 Geological Maps) and is the mapped basal rock type in most of the mountain ranges and some isolated lowland Bay of Plenty areas. Other sedimentary rocks include recent unconsolidated to moderately consolidated clays, silts, sands, tephras and breccias, mapped as Us and occurring mainly as marine, lacustrine and alluvial terrace deposits.

Surface and Interbedded Tephras: These are unconsolidated Holocene or Pleistocene volcanic deposits of ash, lapilli or block size. They are mainly airfall tephras but include significant areas of flow tephra, water-sorted tephra and colluvial units, the products of ***nuees ardentes,*** often intimately interbedded. These two types of deposits are sometimes distinguished as 'tephra-fall' and 'tephra-flow' (Pullar 1980). Most of these deposits are not recorded on NZGS geological maps: apart from field observation, the most important sources of information on tephric rock types were the isopach maps (showing zones of equal thickness of a given tephra) and stratigraphic columns of Healy ***et al.*** (1964a), Vucetich & Pullar (1969) and Pullar & Birrell (1973a). There is also a considerable published literature on the tephrochronology of the region (including further isopach maps), appearing mainly in New Zealand Journal of Geology and Geophysics, giving further information on individual formations. Some of this literature is referred to in Chapter 5.

Some features of the most widespread or significant tephras in the region are summarised in Table 2. An exhaustive annotated list of central North Island tephras is given by Pullar ***et al.*** (1973); the list shown in Table 2 comprises mainly those tephras for which isopach maps are given by Pullar & Birrrel (1973a). The notes to the table summarise the most important changes in the tephrochronology literature for the region since the preparation of Pullar ***et al.'s*** list, as well as other miscellaneous information. The distribution of the principal soil-forming tephras in the region is shown in Fig. 5.

For the NZLRI rock type classification, and arrangement into land use capability suites (Chapter 5), the tephras of the region may be grouped in the following way:

a) Recent airfall tephras (Ngauruhoe and Tarawera Formations). They mantle about 7% of the area of the region*.
b) Tephras of the Kaharoa Formation and Upper Taupo Sub-group, between 1000 and 2000 years old, collectively referred to as 'Kt ashes'. They are lithologically extremely complex, containing flow and water-sorted tephras as well as airfall tephras. They mantle a little under half of the area of the region.
c) Tephras older than Mapara Tephra (tsg 9-10), including lower Taupo Sub-groups, Rotorua Sub-group (Healy ***et al.*** 1964a), Tongariro Sub-group (Topping 1973) and older ashes (Vucetich & Pullar 1969). Together they cover more than 70% of the region either at the surface or below (Table 1) and are significant at all depths; firstly because of the geomorphic significance of the interface between bedding planes (see below), and secondly because of their more weathered nature and the presence of paleosols on many of the older tephra surfaces (Gibbs 1980). This allows the supply of stored moisture and minerals to tree roots which are able to penetrate through the more droughty and infertile surficial tephras.

These tephras are collectively referred to in this bulletin as 'Mo' tephras. They show considerable variation in degree of weathering and texture; as well as airfall ash deposits ('Mo' ashes) they may include extensive deposits of tephric loess and lapilli. The greatest quantities of loess overlie the Okareka, Te Rere and Kawakawa deposits (Kennedy 1980; Pullar & Pollok 1973). Lapilli was usually recorded as an interbedded tephra belonging to either of two formations which had a significant influence on erosion potential. The Waimihia Formation is widespread in the eastern Taupo district, while the Mangaone Lapilli Formation (used in this bulletin in the sense of Pullar ***et al.*** (1973), not as subdivided by Howorth (1975)) is widespread in the Bay of Plenty. (Both these formations, as well as some other tephras of lapilli texture, have been under-recognised in the NZLRI.)

A final group of surficial deposits found in the region include limited areas of lahars, peat, windblown sands, gravels and undifferentiated floodplain alluvium. These are of mixed sedimentary and volcanic origin and therefore are not included in Table 2.

Problems in Mapping Rock Types: Two problems in mapping rock types for the NZLRI were of special significance in the Bay of Plenty-Volcanic Plateau Region. Firstly, the limit of three rock type symbols in the inventory code, while necessary in the interests of clarity, meant that significant rock types sometimes had to be omitted because of the large number of stratigraphically overlapping or interbedded rock types in this region. This was particularly true of areas mantled by Kaharoa and recent ashes.

Secondly, a distinction between 'hard' and 'soft' underlying rock types**, which was an important criterion in the recognition of LUC units, could not be consistently made in the case of the two most widespread volcanic rock types, Vo and Ft. Ignimbrites mapped as Vo contain many unwelded portions while the various volcanic deposits mapped as Ft contained significant well consolidated and even welded members. The present regional land use capability classification has probably under-estimated the importance of differences within tephra deposits relative to differences between underlying rock types. This is especially so for the interfaces between ash and lapilli texture members of the 'Mo' formations, which are often very significant in the initiation of erosion. While the present classification has proved largely satisfactory in respect of soil parent materials, future remapping could pay more attention to lithological differences within mantling deposits and their relationship to

***Other recent tephras of limited distribution, which have not been recognised in the NZLRI classification, are described by Vucetich & Wells (1978).**

****In Chapter 5 the terms stable and unstable are used to describe underlying rock types in an attempt to relate the "hardness" (or degree of welding) of rock types in a generalised way to land use capability.**

relief and erosion.

TABLE 2: Summary of principal tephras of Bay of Plenty-Volcanic Plateau Region (Largely based on Pullar ***et al.*** 1973).

Tephra bed or formation	*Volcanic centre*	*Approx. age (yrs before 1950)*	*Mineralogical composition*	*Distribution*	*NZLRI mapping symbols*	*Notes*
Ngauruhoe Tephra	**Tongariro**	**1800-0**	**Andesitic**	**Volcanic Plateau; Southern Taupo**	**Ng**	
Rotomahana Mud	**Okataina**	**64**	**Hydrothermal**	**Rotorua Basin**	**Rm**	**From same eruption as Tarawera Ash and Lapilli.**
Tarawera Ash and Lapilli	**Okataina**	**64**	**Basaltic**	**Tarawera district**	**Ta**	
Kaharoa Ash	**Okataina**	**930**	**Rhyolitic**	**Widespread in Bay of Plenty**	**Kt**	**Includes small areas of flow tephra and redeposited ashes. Younger age suggested (see p. 63).**
Taupo Pumice	**Taupo**	**1820**	**Rhyolitic**	**Widespread in region**	**Kt, Tp**	**Includes airfall, flow, colluvial and sheet-washed tephra. Considerable lithological variation: Members 9-13 included in IVIO .**
Waimihia Formation	**Taupo**	**3430**	**Rhyolitic**	**Widespread in Taupo and eastern districts**	**Lp**	**Mainly mapped as lapilli but airfall and flow members are interbedded.**
Whakatane Ash	**Okataina**	**5180**	**Rhyolitic**	**Bay of Plenty**	**Mo**	**Intermediate between 'Kt' and 'Mo' tephra.**
Mamaku Ash	**Okataina**	**7050**	**Rhyolitic**	**Rotorua-Mamaku**	**Mo**	
Rotoma Ash	**Okataina**	**8860**	**Rhyolitic**	**Rotorua-Bay of Plenty**	**Mo**	
Opepe Tephra	**Taupo**	**8850**	**Rhyolitic**	**Taupo district**	**Mo**	**Not shown in Pullar *et al.* 1973 but widespread (Vucetich & Pullar 1973).**
Waoihau Ash	**Okataina**	**11250**	**Rhyolitic**	**Widespread in region**	**Mo**	
Mangaone Lapilli Formation	**Okataina**	**30100**	**Rhyolitic**	**Widespread in Bay of Plenty-Taupo**	**Lp, Mo**	**Howorth 1976a). Associated with loess; widely correlated outside region. Subdivided into 5 formations aged between 20500-42000 yrs BP by Howorth (1975). Undermapped in NZLRI.**
Rotoehu Breccia Formation	**Okataina**	**42000**	**Rhyolitic**	**Bay of Plenty**	**Ft, Mo**	**Includes largest airfall deposit in region (Walker 1979).**
Undifferentiated brown tuffs						**Only significant to LUC in northern and western margins of region.**
Hamilton Ash	**Unknown**	**> 50000**	**Mixed**	**Widespread in region**	**Mo**	
Kauroa Ash						**Deeply weathered.**
Pahoia Tuffs						

SOILS

Soil **Mapping:** The soil information on the worksheets is based on published or publicly available soil surveys provided by Soil Bureau, Department of Scientific and Industrial Research. The Bay of Plenty-Volcanic Plateau region is at present (1984) covered by 13 soil surveys: these are listed in Table 3 and their coverage shown in Fig. 6. Table 3 gives a 'short name' for each of the surveys, which is used to refer to that survey in the rest of this bulletin. Of the 13 surveys, four were published at the time of NZLRI mapping, two were unpublished at the time of mapping but have since been published, two have remained

Fig.5: Distribution of principal soil-forming tephras in the Bay of Plenty-Volcanic Plateau Region. Isopach lines used as boundaries between tephric deposits (for Rm approx. 8 cm; for K, Ta, and Ng approx. 15 cm; for T approx. 30 cm) indicate the varying depth at which tephras are significant to LUC. Based on Pullar & Birrell (1973a) and Gibbs (1980).

unpublished, and five were not used at the time of mapping (either because they have been carried out since then, or because they were overlapped by surveys covering larger areas).

In areas which had only soils coverage at 1:253,440 from the General Survey, more detailed soils information was required for the NZLRI. In obtaining this extra detail, the objective was not to prepare a 1:63,360 soil map, but to accurately record, within NZLRI map units, soil sets which were already recognised in the General Survey. For a given area, the relevant sheet of the General Survey was consulted to see which soil sets had been mapped. Using these sets, as defined in the extended legend, together with detailed air photo and field interpretation, boundary detail appropriate to the 1:63,360 scale was recorded. During field work, soil profiles were checked to ensure that the correct soil set had been recorded (Hawley & Leamy 1980).

Fig. 6: Soil surveys used in the Bay of Plenty-Volcanic Plateau Region.

TABLE 3: Soil surveys used in the Bay of Plenty-Volcanic Plateau Region.

Survey No. (Fig. 6)	*Survey name*	*Scale*	*Short name*	*Area of survey (ha)*	*% area of region*
Use of Survey date*	*Author &*				
1	General Survey of the soils a of the North Island, New Zealand		Rijkse in prep, b	1: 63,360	
			Rijkse & Wilde 1977	1: 63,360	Rotorua Survey 94,000 5.3
	Soil map of Taupo County c				
	Soil map of Whakatane c County		Vucetich & Wells 1978	1: 63,360	Kaingaroa Survey 58,800 3.3
	Provisional soil map of the a King Country		Rijkse 1979	1: 63,360	
	Soils, agriculture and a forestry of Waiotapu Region		Vucetich *et al.* 1960	1: 31,680	Piako Survey 7,200 0.4
					Te Puke Survey 34,600 —
	Soils of Rotorua Lakes b District				Whakatane Borough Survey 14,000 —
	Soils, forestry and a agriculture of the Northern Part, Kaingaroa State Forest and the Galatea Basin		Wilson 1980	1: 63,360	
			Cotching (in press)	1: 15,000	Rangitaiki Plains Survey 22,700 —
	Soils of Piako County b		Pullar *et al.* 1978	1: 31,680	
					Wairakei Survey 226 —
	Interim soil survey of part d of the Te Puke District		Pullar (in press)	1: 31,680	Otorohanga Survey 2,400 —
10	Soils and land use of d Whakatane Borough and Environs		Rijkse & Vucetich 1980	1: 6,000	
11	Soils and land use of the d Rangitaiki Plains		Barratt 1981	1: 50,000	
			General Survey	449,800	25.4
12	Soils of Wairakei Research d Station				
13	Soils of part Otorohanga d County		Taupo Survey	441,500	24.8
			Whakatane Survey	392,300	22.0
	NZ Soil Bureau 1954	1:253,440			
			King Country Survey	127,200	7.1
	Rijkse in prep, a	1: 63,360	Waiotapu Survey	118,800	6.7

***a Used as published surveys during NZLRI mapping.**
b Used as unpublished survey during NZLRI mapping, and since published.
c Used during NZLRI mapping but not published.
d Not used during NZLRI mapping but referred to in this bulletin.

As noted above, the soil information recorded is not a new soil map. Because soils are only one of the five inventory factors recorded within a 'homogeneous' map unit area, boundaries of these unit areas need not necessarily correspond exactly to soil boundaries of soil maps covering the same area. For a more detailed soil description and interpretation, users should consult the appropriate soil maps and associated reports. These are listed on the legends of the individual worksheets. Additional information may be obtained from the local Soil Bureau pedologists based in Rotorua.

Soil Groups in the Region: Table 4 shows the soil groups (NZ genetic soil classification, NZ Soil Bureau 1968) occurring in the region. The common feature of almost all the soils in these groups is that their parent materials include significant amounts of volcanic tephra. The only exceptions to this are a few of the steepest slopes, and a narrow strip of windblown sand along the Bay of Plenty coast. In the gleyed recent soils from alluvium and in the organic soils, however, the volcanic materials have been alluvially redeposited and may be mixed with alluvium from other sources.

TABLE 4: Soil groups of the Bay of Plenty-Volcanic Plateau Region.

	Area covered (ha)	*% of region*	*Main LUC Suite (Chapter S)*
Yellow-brown pumice soils	**585,500**	**30.2**	**4b, c; 7b-d, f-i**
Yellow-brown loams ..	**48,600**	**2.7**	**1**
♦Composite yellow-brown pumice soils on yellow-brown loams	**147,300**	**8.3**	**4a, 7a**
Recent soils from volcanic ash	**86,700**	**4.9**	**6**
♦Composite recent on yellow-brown pumice soils	**73,500**	**4.1**	**4b**
Podzolised soils	**277,700**	**15.6**	**5, 7c**
Recent and gleyed recent soils from alluvium ..	**31,900**	**1.8**	**3,**
Gley soils	**15,900**	**0.9**	**3, 7f**
Organic soils	**21,100**	**1.2**	**3, 7f**
Yellow-brown sands	**9,500**	**0.5**	**2**
Yellow-brown earths	**1,700**	**0.1**	**1**
Brown granular clays	**1,900**	**0.1**	**1**
Steepland soils	**417,300**	**23.4**	**8, 7e**
Mountain soils and bare rock	**19,100**	**1.1**	**8**
Unmapped areas	**90,300**	**5.1**	**–**

♦Incorrectly described as intergrades in the NZLRI regional extended legend.
Note: Some soil groups have been amalgamated for simplicity. For example, recent and gleyed recent soils (including saline recent soils), all podzolised soils and all steepland soils.

Further information about the soil groups listed in Table 4, especially relating to land use capability, is contained in the various sections of Chapter 5. Information about the properties of soils within the region can be obtained from a number of accounts of the soils of the region, such as NZ Soil Bureau (1968), National Resources Survey (1962), Vucetich & Wells (1978), and Gibbs (1968, 1980). Much information is also to be found in the unpublished series "Soil Groups of New Zealand", produced by the NZ Society of Soil Science. Appendix 3 gives a list of all soil series and soil sets recorded in the NZLRI in the region, and the survey or surveys in which they are mapped.

SLOPES

The slope groupings recorded for each map unit are standard for land resource mapping (Soil Conservation and Rivers Control Council 1969). Slopes recorded are those areally dominant in each map unit. Compound slopes (where more than one major slope grouping occurs, e.g., A + "B), slopes which are borderline between two slope groupings (e.g., A/B), and dissected slopes (e.g., A') are also recorded.

An analysis of the dominant slope groups in the region is given in Table 5, which also shows the proportion of the various slope groups in the North Island. A comparison of information in this table shows that although the Bay of Plenty-Volcanic Plateau Region has proportionately less flat land than the rest of the North Island, it has more undulating to rolling land and less moderately steep to very steep land. This is a further consequence of the volcanic landscapes, in that hill and valley systems have tended to be 'evened out' by mantling airfall tephras or overland flow tephras. Also, the extensive ignimbrite sheets usually have an undulating to rolling topography. Dissected surfaces are very common in the region.

TABLE 5: Areas of dominant slope groups recorded in the Bay of Plenty-Volcanic Plateau Region, compared with the North Island.

Dominant slope group	*Area (ha)*	*% region*		*% North Island*	
A (0-3)	**211,800**	11.9		14.8	
B (4-7)	**192,900**	10.8	**23.6**	6.4	15
C(8-15)	**228,000**	12.8		8.9	
D (16-20)	**198,100**	11.1		12.8	
E (21-25)	**399,900**	22.5		24.5	
F (26-35)	**343,000**	19.3	**48.4**	22.8	**54.9**
G (>35)	**117,200**	6.6		7.6	
Unmapped	**90,300**	5.1		2.2	

EROSION

Erosion mapping is based on the NZLRI erosion classification (Eyles, in press). For each map unit, erosion severity and type was assessed. Erosion mapping was based on aerial photograph interpretation and field work, aided by knowledge of geological, soil and climatic factors affecting the erosion pattern.

The types of erosion recorded in the region are shown in Table 6, together with the total area of map units within the region affected by each type of erosion. It is important to realise that the methods used to record most types of erosion in the NZLRI ***do not give actual areas of erosion;*** because erosion is assessed ***within*** a map unit whose boundaries reflect other physical factors, only ***areas of map units in which erosion occurs*** can be obtained.

TABLE 6: Types of erosion occurring in the Bay of Plenty-Volcanic Plateau Region.

Erosion type	*Inventory code*	*Area of map units affected (ha)**	*(% of region)**	*Number of map units affected*	*(% of region)*
Sheet	**.. Sh**	**320,900**	**18.1**		**22.1**
Soil slip	**.. sSl**	**264,500**	**14.8**		**12.7**
Debris avalanche	**.. daF**	**168,300**	**9.4**		**4.4**
Gully . .	**.. G**	**142,800**	**8.0**		**9.5**
Streambank	**.. Sb**	**45,700**	**2.6**		**3.6**
Wind . .	**.. W**	**26,300**	**1.5**		**1.1**
Scree	**.. Sc**	**16,400**	**0.9**		**0.7**
Tunnel gully	**.. T**	**7,300**	**0.4**		**0.4**
Deposition	**.. D**	**6,600**	**0.4**		**0.3**
Earth slip	**.. eS**	**5,400**	**0.3**		**0.3**
Rill	**.. R**	**4,800**	**0.3**		**0.4**
Slump	**.. Su**	**700**	**0.0**		**0.1**
No erosion recorded	**. . 0**	**940,000**	**52.8**		**57.6**

***Adds up to more than total of region because each erosion type recorded within a map unit (up to 3 allowed) is counted separately for that map unit.**

With surface erosion types (sheet, wind and scree erosion), the assessment of severity (or more correctly, degree) of erosion relates to a percentage of bare ground on the following basis: 0 = 0-1%, 1 = 1-10%, 2 = 11-20%, 3 = 21-40%, 4 = 41-60%, 5 = > 60%. An approximate area of erosion could therefore be calculated in these cases; however this has not been done in this bulletin. With mass movement and fluvial erosion (all other erosion types), severity is assessed subjectively according to the following scale: 0 = insignificant, 1 = slight, 2 = moderate, 3 = severe, 4 = very severe, 5 = extreme. No calculations of actual areas of erosion can thus be made.

In a regional context, i.e., when dealing with large numbers of .map units, a different approach is to assess overall erosion severity in terms of ***number*** of map units affected by erosion, rather than area. This has been done in Table 6, as well as in Tables 11-33 in Chapter 5. This approach also enables an appreciation of whether a particular erosion type is over-represented in areal terms because it occurs in a few very large map units; this has occurred in a few instances, which are mentioned in Chapter 5.

Table 7 shows the severity of erosion occurring in the Bay of Plenty-Volcanic Plateau Region (taken as the severity of the first erosion type recorded in each map unit). Compared with the North Island as a whole, the Bay of Plenty-Volcanic Plateau Region has a much larger area without significant recorded erosion and a correspondingly smaller area affected by erosion (at all recorded levels of severity). This may be related to a greater proportion of land of gentle relief, where erosion is not the dominant limitation to use, but is certainly related to land use patterns in the region because a proportionately much greater area is under forest cover. It is also interesting to note (Table 6) that although sheet erosion (involving mainly surficial ashes) is the most prevalent erosion form, the three next most widely recorded types are all mass movement or fluvial types, often involving or even intiated in deeper tephra layers.

TABLE 7: Rankings of erosion severity recorded in the Bay of Plenty-Volcanic Plateau Region, compared with the North Island,

a) Surface erosion types

Erosion ranking		*Area of map units affected*		*Area affected in North Island (%)*
Rank	***% bare ground***	***ha***	***% region***	
0	**0-1**	**940 000**	**52.8**	**38.1**
1	**1-10**	**211 700**	**11.9**	**9.6**
2	**11-20**	**36 500**	**2.0**	**3.1**
3	**21-40**	**7 900**	**0.4**	**1.16**
4	**41-60**	**3 300**	**0.2**	**0.3**
5	**<60**	**7 500**	**0.4**	**1.0**

b) Mass movement and fluvial erosion types

Erosion ranking		*Area of map units affected*		*Area affected in North Island (%)*
Rank	***% bare ground***	***ha***	***% region***	
0	**Insignificant**	**940 000**	**52.8**	**38.1**
1	**Slight**	**389 500**	**22.0**	**33.6**
2	**Moderate**	**88 800**	**5.0**	**11.8**
3	**Severe**	**5 700**	**0.3**	**2.2**
4	**Very severe**	**0**	**0**	**0.6**
5	**Extreme**	**0**	**0**	**0.2**

Significant combinations of erosion types (termed erosion associations) are mapped at 1:250,000 in the "Erosion Map of New Zealand Series", sheets 5 and 8 (Steel 1982; Page & Steel 1983) with small areas on sheets 4 and 7 (Robins 1974a, b). See Appendix 5 for description of erosion associations presented in that series. In the Bay of Plenty-Volcanic

Plateau Region, the following four major combinations of erosion types are recognised by the present author.

1) Sheet, by itself or with associated soil slip, on ash-covered surfaces of gentle to moderate relief. This partially correlates with erosion association P and also includes associations G and H. It is probably the most extensive combination in the region.
2) Sheet, wind and scree erosion on younger ashes in elevated and exposed situations where existing vegetation is mainly non-woody; also on sand dunes. Partially corresponds with erosion associations E, B and T, depending on location within the region.
3) Gully or streambank, with associated sheet, on unconsolidated tephric deposits (usually flow tephra) on flat to gently rolling areas of plains or valley bottoms. Correlates with erosion association R, and includes erosion association S.
4) Debris avalanche and/or soil slip in mainly forested steep mountain areas where the ash cover is more weathered and variable. Correlates with erosion association C.

Of these four combinations, the first two are dominated by surface erosion (in the case of the first, with associated mass movement erosion), the third by fluvial erosion with associated surface erosion, and the last involves mainly mass movement associations. In terms of actual erosion types, the four combinations are dominated by the four most extensive erosion types identified in Table 6, viz. sheet, soil slip, debris avalanche and gully. Sheet erosion is associated with all main combinations except the last. Of the other erosion forms shown in Table 6, wind, scree and streambank (the three next most extensive types) are important in combinations (2) and (3) above. Wind and scree creep are unusual in being more commonly recorded at severe to extreme severity rather than at slight to moderate severity.

The other recorded erosion types are mainly subsidiary. Rill and tunnel gully is associated with sheet and gully erosion on arable land, earth slip is associated with soil slip, and slump is only of significance at very localised scales. Deposition (not strictly an erosion type) is causally connected with all other erosion forms, but was very rarely recorded at the scale of mapping.

A number of studies have been made of mass movement and fluvial erosion within the region, especially of gully erosion. These will be referred to in relevant sections of Chapter 5. The effect of short-duration high intensity tropical storms on mass movement erosion (mainly soil slip and debris avalanche) in the Bay of Plenty has been noted (Pullar ***et al.*** 1978), and some attempt has been made, in tracing the causes of gully erosion, to determine the relationships between erosion and land use. This has highlighted the importance of runoff processes (Selby 1973, see also p. 9). The failures of several engineering structures in the region, e.g., the Ruahihi and Wheao Canal failures of 1981 and 1982, have generated several recent geotechnical investigations into the engineering stability of volcanic ash soils (Hatrick ***et al.*** 1982; Jones ***et al.*** 1983).

There remain several problems in the region regarding erosion processes and their effect on land use capability, among which two of the most important could be mentioned. The first is the role of the interface between tephra layers of different densities and permeabilities, in the initiation of mass movement and fluvial erosion (see for example p. 84). Secondly, regarding surface erosion, the degree of surface erosion was mapped according to the amount of bare ground observed, but the relationship of soil loss to bare ground, and the contribution of environmental factors to that relationship, has not been tested (Eyles, in press). The effect of stock in the initiation of sheet erosion is probably very significant, but the interaction of physical soil disturbance by stock, compaction, and surface runoff processes is a complex and little-understood problem.

VEGETATION

Vegetation cover was assessed for each map unit, using a classification of 45 vegetation classes arranged in five major groups: grassland, cropland, scrubland, forest and miscellaneous (Hunter & Blaschke, in press). Up to three vegetation classes were recorded in each map unit, in descending order of percentage cover. Information on vegetation cover was derived

from aerial photograph analysis and field work, supplemented by published maps and descriptions for forested areas.

Most of the indigenous forests of the region are covered by Forest Service Mapping Series 6, at a scale of 1:250,000 (sheets 5, 7, 10) and by FSMS 5 at a scale of 1:63,360 (sheets N58, 66-68, 75-77, 86-7, 95-6, 104). A vegetation map of Tongariro National Park at a scale of 1:50,000 (Atkinson 1981) has been published since NZLRI mapping was completed. Several general descriptions of the main forested areas are available, including for the Kaimai Range Dale & James (1977) and Jane & Green (1983a), for the Urewera ranges McKelvey (1973) and Grant (1963), for the Kaimanawa Range Elder (1962), and for the West Taupo area McKelvey (1963) and Herbert (1978).

The overall vegetation pattern for the region has been briefly described in the section on present land use (Chapter 2). The considerable influence of Polynesian people on the vegetation, before the time of intensive European settlement, has also been mentioned. In the following paragraphs a brief summary of the 'indigenous' vegetation is given although this term is highly subjective in the light of the complex history of the vegetation in terms of climatic fluctuations (McKelvey 1963; Grant 1963), volcanic (Nicholls 1963) and cultural disturbance (Fletcher 1914; Ward 1956; Cameron 1964; McGlone & Topping 1977; McGlone 1983). The last was particularly marked in coastal districts and around many lakes.

The climax vegetation over most of the region is lowland podocarp-broadleaved forest, with rimu, matai, miro, and totara the most important podocarps and tawa, kamahi, maire and hinau the most important broadleaved species. (Broadleaved species are referred to in the NZLRI vegetation classification and throughout Chapter 5 as 'hardwoods'.) Tawa is the dominant broadleaved species, especially north of Lake Taupo, and now dominates large areas from which podocarps have been milled. Small areas of dense podocarp forests (in which broadleaved species are rare or absent) occur, notably on the eastern and northern fringes of the Hauhungaroa Range and in northern Whirinaki State Forest. Kauri-podocarp-broadleaved forest occurs in a small area north of Tauranga. Broadleaved-dominant forest is normally the result of logging or fires, but also occurs as a result of primary succession, e.g., around Mt Tarawera following the 1886 eruption (Nicholls 1959, 1963). Important broadleaved trees in these generally successional stands are kanuka, rewarewa, five-finger, ***Pittosporum*** and ***Coprosma*** species, as well as various lower-statured broadleaved shrub species. Extensive podocarp-broadleaved-beech forest occurs in the Urewera ranges, pure beech forest in the Huiarau and Kaimanawa Ranges and in the north-eastern Tongariro National Park, while small pockets of beech trees occur widely within other forest types.

Tussock grassland occurs naturally on the Volcanic Plateau and the Upper Rangitaiki Plains. It may also have formerly occurred more extensively in upland areas to the east of Lake Taupo. On the Volcanic Plateau red tussock is the most important tussock species but at higher altitudes bristle tussock occurs together with small subalpine shrubs and mountain inaka (snow tussock recorded on NZLRI worksheets in this area is in error). On the Upper Rangitaiki Plains, the main tussock is silver tussock.

Scrubland and fernland occur widely as a result of natural and cultural disturbance. Indigenous scrubland ranges from pure manuka stands to floristically diverse broadleaved shrub assemblages in which manuka, bracken, karamu, five-finger, tutu, tree ferns and monoao are variously dominant, composition being related to soil type (McQueen 1961). For example, monoao-dominated heathland is thought to occur mainly on Taupo flow tephra. The Kaingaroa Plateau before afforestation was entirely covered by low scrubland (Ure 1950) but this is thought to have been culturally maintained. Related scrublands and fernlands in the region, in which manuka, monoao, wire rush and umbrella fern are conspicuous, may be described as heathlands (Burrows ***et al.*** 1979).

CHAPTER 4: LAND USE CAPABILITY CLASSIFICATION

PRINCIPLES OF LAND USE CAPABILITY CLASSIFICATION

The land use capability (LUC) classification is an assessment of the land in terms of its capacity for sustained productive use, taking into account physical limitations, management requirements and soil conservation needs. The LUC assessment in the NZLRI is based on an interpretation of the physical factor information in the land resource inventory, together with information on climate and the effects of past land use.

The LUC classification has three components—class, subclass and unit—each of which is represented by a number or symbol.

Land Use Capability Class

The LUC class is the broadest grouping in the capability classification. It gives an assessment of the overall degree of limitation to use and the versatility for sustained production, taking into account the physical limitations. There are eight classes, represented by roman numerals, with limitations to use increasing and versatility of use decreasing from class I to class VIII. Classes I-IV are suitable for arable use as well as pastoral or forestry use, while classes V-VII are not suitable for arable use but are suitable for pastoral or forestry use. The limitations reach a maximum with class VIII land, which is unsuitable for agriculture or forestry but is best suited to catchment protection.

Areas and proportions of the eight LUC classes mapped in the Bay of Plenty-Volcanic Plateau Region are shown in Table 8, together with areas and proportions for the North Island as a whole. Comparison of the areas shows that although there is proportionately much less LUC class I and II land (most versatile) than in the North Island as a whole, there is much more class IV land, resulting in a similar proportion of arable land. The proportion of non-arable land is slightly less, while the proportion of LUC class VIII land is slightly greater, as is unmapped land (principally lakes and urban areas).

TABLE 8: Land use capability classes of the Bay of Plenty-Volcanic Plateau Region, compared with the North Island.

LUC class	*Area (ha)*	*% of region*	*% of North Island*
I	**2,850**	**0.2'**	**1.3]**
II	**42,300**	**2.4 ^30.0**	**6.41 27.9**
III	**145,050**	**8.1 " (Arable land)**	**8.91 (Arable land)**
IV	**343,750**	**19.3**	**11.3 J**
V	**650**	**0.0" 55.4**	**0.81 61.1**
VI	**595,350**	**33.4 > (Non-arable**	**35.2 > (Non-arable**
VII	**392,450**	**22.0 land)**	**25.1J land)**
VIII	**168,500**	**9.5 (Protection land)**	**8.7 (Protection land)**
Unmapped	**90,350**	**5.1**	**2.4**

Land Use Capability Subclass

The LUC subclass is a subdivision of the LUC class according to the main kind of physical limitation or hazard to use. The four kinds of limitation recognised in the NZLRI classification are erodibility, soil limitations within the rooting zone, wetness, and climate. The subclass is identified by the initial letter e, s, w, or c, as a modifier of the LUC class in the LUC code. Only the dominant limitation is shown in the LUC classification, e.g., a LUC unit assessed as having a dominant erodibility subclass may well have a climate limitation as well.

The areas of the four subclass limitations for the region and for the North Island as a whole are shown in Table 9. This table shows that, compared with the North Island, the

region has a greater proportion of land whose dominant limitation arises from the coarse infertile nature of the soils, and a smaller proportion of land with a dominant wetness or climatic limitation. However, as with the rest of the North Island, the dominant limitation over nearly 80% of the area is erodibility.

TABLE 9: Area of dominant subclass limitations in the Bay of Plenty-Volcanic Plateau Region, compared with the North Island.

LUC subclass	*Area (ha)*	*% of region*	*% of North*
Climate	**8,750**	**0.5**	**4.0**
Erodibility	**1,399,950**	**78.6**	**77.3**
Soil	**233,500**	**13.1**	**9.2**
Wetness	**48,800**	**2.7**	**7.3**
Unmapped	**90,350**	**5.1**	**2.2**

Land Use Capability Unit

The LUC unit is the most detailed component of the LUC classification. LUC subclasses are subdivided into a number of LUC units (represented by an arabic number at the end of the LUC coding), each of which:

> "groups those inventory units [map units] which respond similarly to the same management, are adapted to the same kinds of crops, pastures, or forest species, have about the same potential yield, and require the application of the same conservation measures" (Soil Conservation and Rivers Control Council 1969).

Map units within a LUC unit would normally have a similar, though not necessarily identical inventory. In the regional extended legends, LUC units within each LUC subclass are ranked in approximate order of decreasing versatility of use and potential production.

A total of 110 LUC units were recognised in the region and described in the NZLRI LUC extended legend (Steel 1979). They are listed in Appendix 2, together with a correlation to similar LUC units in adjacent NZLRI regions (Waikato, Coromandel-Great Barrier Island, Eastern Bay of Plenty, Northern Hawke's Bay, and Taranaki-Manawatu) and a list of their North Island correlation LUC units (Page 1985).

Land Use Capability Suite

The traditional numerical ranking of LUC units based on decreasing versatility and capability, as shown in the LUC extended legends, gives no direct indication of the relationships between LUC units in their actual landscape setting. To enable these relationships to be better understood and to aid interpretation of the worksheets and extended legends, related LUC units are arranged into groups, called LUC suites. An LUC suite is defined as follows:

> A group of LUC units which, although differing in land use capability, share a definitive physical characteristic which unites them in the landscape.

The 'definitive physical characteristic' may vary from region to region. LUC suites may be divided into subsuites according to secondary criteria. The arrangement of LUC units into LUC suites and subsuites in the Bay of Plenty-Volcanic Plateau Region is described at the beginning of Chapter 5.

PREVIOUS LAND USE CAPABILITY SURVEYS IN THE REGION

Prior to the commencement of the NZLRI survey in the region in 1977, a number of LUC surveys had been carried out at various scales by various agencies. Much of the Bay of Plenty-Volcanic Plateau Region, including the whole of the Lake Taupo catchment, the Rotorua Lakes and Kaituna River catchments, and Whakatane County were mapped for LUC at scales of 1:63,360 and 1:250,000 by the forerunner of the present Land Resources Group, the LUC Survey team of Water and Soil Division, Ministry of Works and Development. With the exception of the Kaituna Catchment survey (Nairn 1975) these

surveys and reports were not published, but were important sources of information for the NZLRI. The Lake Taupo LUC survey was also a major input into the Lake Taupo Catchment Control Scheme (Waikato Valley Authority 1973). The experience gained in these surveys greatly assisted the design of the present regional LUC classification.

Ir. addition, Ministry of Works and Development soil conservators have prepared more detailed surveys (mainly at 1:20,000) of all land development and some Maori land blocks in the region for the Lands and Survey Department, of Tauranga Harbour and various other catchments in the Bay of Plenty, e.g., Waingaehe, Horomanga, for the Bay of Plenty Catchment Commission, and of all hydrological research areas in the Taupo district. Of these, only the survey of the Ngatiawa farm block near Whakatane was published (Stephens, in Pullar ***et al.*** 1978).

Staff of all three catchment authorities in the region have prepared many LUC assessments of areas under their jurisdiction for farm plans, catchment control schemes (e.g., Whirinaki Arm of the Waikato River, including the Paeroa Range, prepared by Waikato Valley Authority), or for general planning purposes.

ASSESSMENT OF AGRICULTURAL AND EXOTIC FORESTRY POTENTIAL

An important extension of the original NZLRI database has been the addition of two sets of data to the inventory information and LUC assessments. These relate to present and potential pastoral and exotic forest performance. They are expressed in terms of stock carrying capacity in stock units per hectare, and site index for ***Pinus radiata*** (mean top height or predominant mean height in metres at age 20 years). These data are not shown on NZLRI worksheets but are shown on some regional legends and are recorded in the computer data base. This has allowed more specific and quantitative application of the NZLRI to agricultural and forestry planning. The Bay of Plenty-Volcanic Plateau Region was the first in which these data were collected at the time of the finalisation of the LUC classification and incorporated into the extended legend. For each LUC unit, the data are shown in Tables 11-33, and discussed in the text of Chapter 5*.

Data on stock carrying capacities were collected in 1978 as a combined project with Ministry of Agriculture and Fisheries advisory staff from Tauranga, Whakatane, Rotorua and Taupo. Representative sites of each LUC unit were visited, where assessments of present average, top farmer and potential carrying capacities were given. An assessment of fertiliser and trace element requirements for establishment and maintenance of pasture was also made at the time of field inspection. Correlation of the stock carrying data was carried out by the NZLRI regional supervisor and MAF regional advisory officer. Stock carrying data for all North Island regions are available on the computer data base. The following ranking of potential stock carrying capacity figures has been made:

Potential Stock Carrying Capacity Ranking	***Potential Stock Carrying Capacity (stock units/ha)***
Very high	**>25**
High	**21-25**
Moderately high	**16-20**
Medium	**11-15**
Low	**6-10**
Very low	**1-5**
Sparse	**< 1**

***A few potential productivity and site index figures discussed in Chapter 5 vary from those published in the regional extended legend. During the correlation of all North Island LUC units (Page 1985), slight inconsistencies with respect to other regions were noted for a few LUC units, and some adjustments were made to Bay of Plenty-Volcanic Plateau Region figures as a result. These have been incorporated in the computer data base.**

Site index data were collected in 1979 with the assistance of foresters from New Zealand Forest Service. Site indices were based on plot trial records, or on an extrapolated and interpreted age height to altitude relationship (Mountford 1979), and checked at representative field sites. In this region, depressions in site index from a general altitude-site index regression reflect either very coarse soils, subsoils with impeded drainage, or high water table.

Site index data were correlated by the NZLRI regional supervisor and the Senior Forester, Rotorua Conservancy. Site index data for all North Island regions are available on the NZLRI computer data base. The following ranking of site index figures has been made:

Exotic Forest Growth Potential	***Site Index for P. radiata***
Very high	>35
High	30-35
Medium	25-29
Low	20-24
Very low	<20

Because of the technique used for assessing site index in this region, a wider range of potential site index values for most LUC units was given in the regional extended legend than was sub sequently derived for other regions. As a generalisation, a satisfactory way of achieving consistency with site index ranges given for other regions, is to give a range of 4-5 m around the mean of the range presently quoted.

CHAPTER 5: LAND USE CAPABILITY SUITES IN THE REGION

DELINEATION OF LAND USE CAPABILITY SUITES AND SUBSUITES

Light LUC suites (Table 10) have been distinguished in the Bay of Plenty-Volcanic Plateau Region. Their distribution is shown in Fig. 7. The primary factor used to delineate these I.UC suites is soil parent material, as determined by the tephra deposits described in Chapter 3. Four groups of soil-forming tephras (see p. 19) are of particular significance in defining LLC suites: a) 'Mo' ashes and lapilli, b) Taupo Pumice Formation and Waimihia Formation, c) Kaharoa Ash, d) Recent deposits (Tarawera Formation and Ngauruhoe Tephra).

Of the eight LUC suites, four are defined directly by their derivation from the above tephra deposits (LUC suites 1, 4, 6, 7). Three have soil parent materials that are wholly or partly tephric in origin, but of mixed composition, differing in their mode of deposition and post-deposition history (LUC suites 3, 5, 8). Only one has soil parent materials not primarily derived from tephra (LUC suite 2).

Four of the eight LUC suites have been subdivided into varying numbers of subsuites. The number and distinguishing criteria of subsuites within LUC suites subdivision have varied; the depth and texture of the tephra deposits were important in some cases, but in others, factors of climate and underlying rock types were also important*. A total of 22 LUC suites or subsuites were distinguished in the region; these are listed in Table 10. The listing of LUC units in Appendix 2 also shows for each LUC unit its LUC suite or subsuite and a page reference to the description of the LUC unit in this bulletin.

It should be recognised that although the concept of LUC. suites is emphasised in this bulletin, and was implicit in the design of the LUC classification and extended legend for the region, LUC suites were not formally defined at the time of mapping. For this reason there are a number of LUC units which do not fit exactly into one LUC suite or subsuite. This applies especially to LUC suite 7 on Taupo Pumice which because of its size and complexity has considerable overlap between its subsuites. At other times, a subjective decision had to be made as to which tephra was more important to land use capability in order to select the best LUC unit in which a given map unit should be placed.

FORMAT OF LUC SUITE DESCRIPTIONS

The rest of this chapter gives a detailed description of the LUC suites, subsuites and units in the Bay of Plenty-Volcanic Plateau Region. The LUC suites are described in approximate order of occurrence from north to south of the region.

LUC Suites and Subsuites

For each LUC suite, or subsuite where the LUC suite is so divided, a general account is given under the following headings:

1. **General:** Describes distinguishing characteristics, distribution, area, number of LUC units, and related LUC suites.

2. Climate: A very brief description of the overall character of the climate. Climate data from a representative climate station for each LUC suite/subsuite are given in Appendix 4.

3. **Physiography:** A short description of major landscape features, including summary of relief data.

4. **Rock type and soil parent material:** Summarises information given in the rock type inventories, including both surficial and underlying rock types.

***The distinction made in this bulletin between LUC suites and subsuites is not as precise as has been made in the description of the LUC classification in other regions (e.g., Noble 1985, and work in progress in the Taranaki-Manawatu and Northern Hawke's Bay Regions). As used in this bulletin, LUC suites and subsuites are almost interchangeable, e.g., the three subsuites on recent tephras could in terms of the definition of LUC suites, be validly described as separate LUC suites.**

TABLE. 10: LUC suites and subsuites in the Bay of Plenty-Volcanic Plateau Region.

LUC suite/subsuite number	*LUC suite/subsuite name*
1	**Yellow-brown loams**
2	**Windblown sand**
3	**Alluvium**
4	**Kaharoa Ash**
4a	**Shallow Kaharoa Ash**
4b	**Deep Kaharoa Ash**
4c	**Kaharoa Ash over lapilli**
5	**Podzolised yellow-brown loams**
6	**Recent tephras**
6a	**Tarawera Ash and Lapilli**
6b	**Rotomahana Mud**
6c	**Ngauruhoe Ash**
7	**Taupo Pumice**
7a	**Shallow Taupo Pumice**
7b	**Moderately deep fine Taupo Pumice**
7c	**Deep Taupo Pumice in high rainfall areas**
7d	**Deep Taupo Pumice in low rainfall areas**
7e	**Taupo Pumice on steeplands and mountainlands**
7f	**Taupo flow tephra and water-sorted tephra**
7g	**Complexes of Taupo tephras**
7h	**Taupo Pumice on the Kaingaroa Plateau**
7i	**Taupo Pumice over Waimihia Lapilli**
8	**Steeplands and mountainlands**
8a	**General steeplands and mountainlands**
8b	**Steeplands on Tertiary rocks**
8c	**Steeplands on hard volcanic rocks**

5. Soils: Brief discussion of major soil groups, including summary of soil surveys used. Note that shortened soil survey names are used throughout this chapter (see Table 3 for full survey names).

6. **Erosion:** Summary of general nature and extent of erosion, erosion severity and type. Includes assessment of potential erosion and erosion associations (see Appendix 5).

7. Land use and land management: Discussion of present land use pattern (including brief mention of vegetation cover), limitations to use, trends in land use and discussion of recommendations given in NWASCO (1982). Vegetation terms used are defined in Hunter & Blaschke (in press); scientific names of plants are given in Appendix 6. Soil conservation is discussed briefly, with emphasis on objectives rather than specific measures, and on the necessity to adhere to the "Forest Operations" guidelines (NWASCO 1976). Further details are given in the regional extended legend.

LUC Units

LUC units in each LUC suite/subsuite are described principally by means of a summary table which follows the format described below. The summary tables are in effect a summary of information contained in the regional LUC extended legend, arranged by LUC suite/subsuite rather than by LUC class/subclass. The summary diagrams are accompanied by a short written commentary of each LUC unit and its significant features. These should be read in conjunction with the summary tables. Each LUC unit is illustrated by one or more photographs. All photographs were taken by the author unless otherwise acknowledged.

The main sources of information for these descriptions, apart from the regional LUC extended legend, were computer summaries of NZLRI information derived using the

I ADl'.DA program. All percentages have been rounded off and are given as a guide only. All areas are rounded off to the nearest 50 ha, and are accurate as at November 1984. These may change due to periodic alterations to the NZLRI data base.

An attempt has been made throughout this bulletin to relate descriptive information to its appropriate scale of applicability, i.e., features relevant to the whole region are described in Chapters 2 and 3, features common to individual LUC suites/subsuites are dealt with in the general description of that LUC suite/subsuite, while only features relevant to individual LUC units are described in the LUC unit description. Although some repetition has been

Fig. **7:** Distribution of the eight LUC suites delineated in the Bay of Plenty-Volcanic Plateau Region. More detailed maps showing distribution of subsuites are shown in Fig. 8, 25, 42, 55, 100.

necessary in the interest of coherence, no attempt has been made to make each LUC unit description comprehensive.

Format of the Summary Tables of LUC Units (Tables 11-33)

1. **LUC unit.**
2. **Related LUC unit and LUC suite:** Refers to LUC units physiographically linked to the LUC units being described, either within the described LUC suite/subsuite, or bordering it. These are usually also mentioned in the text.
3. **Physiography:** Is briefly described, and shown on an idealised cross-section.
4. **Area:** Mapped area of LUC unit, to nearest 50 ha.
5. **Slope:** Shows the most common slope groups or slope group combinations (up to 3), in order of areal extent. For key to slope group symbols used, see Table 5.
6. **Soils:** Shows the most common soils in order of total areal extent in all soil surveys used for mapping that LUC unit. Up to three soil names are shown (provided each has a minimum recorded cover of about 10% of the LUC unit area), or four for the more extensive or variable LUC units. The soil names shown are usually those of soil series, except when referring to the General Survey when they are soil set names. A name which has been used in both the General and subsequent surveys (e.g., Taupo) may thus be both a soil set and soil series name. A listing of all soil sets and series used in the region in the NZLRI is given in Appendix 3. This listing also indicates in which survey or surveys each soil name has been used, arid thus its status as set or series. Soil names in brackets indicate soils from recent surveys, e.g., Te Puke survey, which were not used in the NZLRI but which relate to that LUC unit.
7. **Percentage map units containing erosion:** Gives an indirect measure of the amount of land affected by erosion. Because of the problems associated with measuring mass movement erosion on an areal basis (see p. 25), this measure is expressed as the percentage of map units in the LUC unit in which some erosion is recorded.
8. **Present erosion:** Shows the significant erosion types recorded in the LUC unit, in order of severity, and the range of severity recorded. Minor erosion forms affecting only a few map units are not shown. For key to erosion type and severity symbols see Tables 6 and 7.
9. **Potential erosion:** Gives an assessment of the significant potential erosion types to be found in the LUC unit, and their potential severity, in order of severity. The assessment has generally been taken from the regional extended legend, but may vary slightly in the light of the analysis of present erosion, and further knowledge of the total variability of the LUC unit. For arable LUC units an assessment of potential erosion under non-arable use is given, followed by an assessment of potential erosion under arable use, in brackets. For key to erosion type and severity symbols see Tables 6 and 7.
10. **Present land use:** Shows the main land uses in estimated order of area occupied (not necessarily economic importance). This assessment is made using the analysis of vegetation on the LUC unit, the estimate given in NWASCO (1982) and the author's knowledge of regional land use patterns.
11. **Stock carrying capacity:** Gives figures for present average, top farmer, and attainable potential stock carrying capacity in stock units/ha, as described in Chapter 4. A ranking of the potential stock unit/ha values is given on p. 31. The following symbols are used in the summary diagrams:
    - — present or potential level not assessed (usually because there is no developed land on which to make assessment);
    - 0 assessed as zero potential or unsuitable for development;
    - * change from figure in regional extended legend (see p. 31).
12. **Site Index:** Gives an estimate of exotic forest growth potential in terms of Site Index for ***Pinus radiata,*** as described in Chapter 4. A ranking of the Site Index values is given on P. 32. The symbols 0 and * are used as described in the previous paragraph.

LUC SUITE 1: YELLOW-BROWN LOAMS

General

The definitive characteristics of this LUC suite are determined by its location in the northernmost part of the region. This area experiences a mild, almost sub-tropical climate; also its soils were not significantly influenced by the tephra showers of the last 2000 years and have excellent physical properties for plant growth. Because of these two factors, land in this LUC suite has considerable versatility, especially the arable portion, which in the last two decades has seen a rapid intensification and change towards high-value orchard crops, notably kiwifruit. Indeed, for an area which as recently as seventy years ago was covered with dense indigenous forest, fern, and scrub, the transformation through sheep and cattle farming and dairying into intensive horticulture and orcharding has been a dramatic one, and one which is likely to continue.

The distribution of the LUC suite around Tauranga Harbour is shown in Fig. 8. It is bordered to the west and south by the Kaimai Range*, the dissected northern part of the Mamaku Plateau and the Kaharoa Plateau (LUC suites 8, 5 and 4). The northern boundary of the LUC suite runs along the top of NZMS1 sheet N57, dividing the Bay of Plenty-Volcanic Plateau Region from the Coromandel-Great Barrier Island Region. LUC units on yellow-brown loams directly correlate across this regional boundary.

This LUC suite occupies an area of 31,300 ha, 1.8% of the total area of the region. There are six LUC units: IIel, IIIel, IVel, Vcl, VIel, and VIe2. They are separated according to slope, with the non-arable LUC units being further separated according to underlying rock type. In areas fringing the Tauranga Harbour, arable LUC units in this LUC suite are closely related to LUC units with soils derived from rhyolitic alluvium (LUC suite 3). Many parts of the LUC suite are intersected by steep valley sides, gullies and gorges, which are mapped as VIIe4 or VIIIe3 (LUC suite 8).

LI C suite 1 grades into LUC suite 4 in the south and south-east, and into LUC suite 5 in the south-west, along gradients of increasing depth of Kaharoa Ash and increasing soil leaching respectively. Along most of their boundary however, LUC suites 1 and 5 are separated by a band of steep ignimbrite country (VIIe4).

Climate

The climate is one of the most equable in the region. It is characterised by moderate and well-distributed rainfall and mild temperatures, although slight summer soil moisture deficits occur. Rainfall increases markedly towards the north of the LUC suite. Winds are usually mild but the area is affected by north-easterly cylonic conditions, especially in summer, bringing strong winds and heavy rain. Significant frosts occur only between June and August. The representative climate station is Tauranga.

Physiography

Most of the LUC suite occurs in the Tauranga Basin, where Pleistocene fluviatile terraces fringe the Tauranga Harbour and rise to about 150 m a.s.l. The terraces are steeply dissected in places and are interspersed with more recent and lower terrace deposits. To the south of these terraces, and on the fringes of the Kaimai Range, the LUC suite also occurs on stable hill country of generally medium relief, rising to about 300 m a.s.l. near the headwaters of the Aongatete Stream. The terraces and fluviatile deposits, comprising 20% of the LUC suite, are predominantly flat to gently undulating, while about 30% is predominantly rolling to strongly rolling, and the remaining hill country is predominantly moderately steep. Steep slopes were included in LUC suite 8.

*** The boundary between the Bay of Plenty-Volcanic Plateau and Waikato Regions generally runs along the western edge of the Kaimai Range. However, small areas of northern brown granular loams and clays (mapped in the Piako Survey) have been recorded between the edge of the steeplands and the regional boundary, and these have been included within this LUC suite. In future mapping, the regional boundary will be altered so that these areas are included within the Waikato Region.**

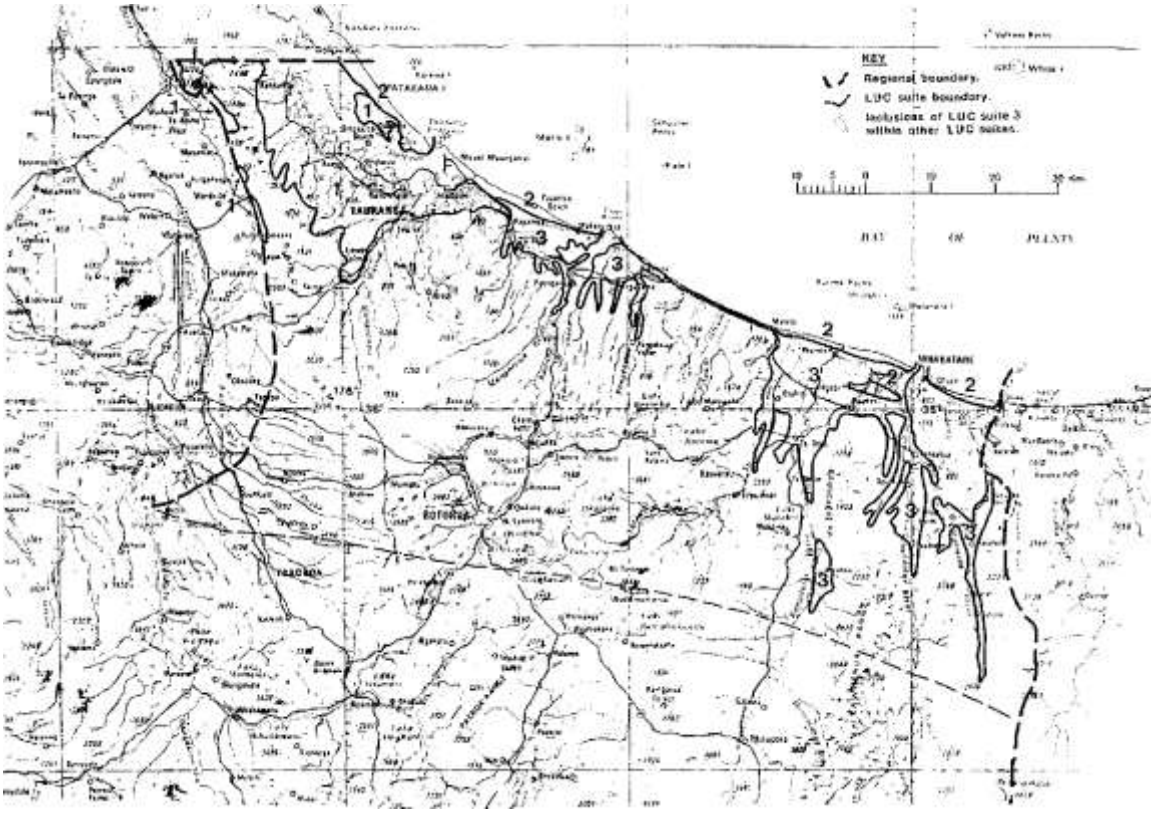


Fig. 8: Distribution of LUC suites 1, 2 and 3 on yellow-brown loams, windblown sands and alluvium in the Bay of Plenty and Rotorua districts. Occurrences of LUC suite 3 south of the thin dotted line are shown in Fig. 55.

Rock Type and Soil Parent Material

The whole LUC suite is mantled by approximately 7-10 m of 'Mo' ashes. Prominent among these are Rotorua Ash, Rerewhakaaitu Ash, Oruanui Ash, Mangaone Lapilli Formation, Rotoehu Ash, undifferentiated brown tuffs and Pahoia Tuffs. (Lapilli from the Mangaone Lapilli Formation was included in 'Mo'.) These soil-forming tephras are often collectively referred to as 'Waihi Ash', a general term for a number of Holocene and late Quaternary tephras derived from north of the region (Gibbs ***et al.*** 1982; Hogg & McCraw 1983). The latter authors, and Birrell ***et al.*** (1977) describe a textural and weathering difference in 'Waihi Ash' between areas to the north and south of approxima tely Katikati, suggesting that the NZLRI boundary between the Bay of Plenty-Volcanic Plateau and Coromandel-Great Barrier Regions reflects a real field difference.

The underlying rock types are either upper Wanganui-lower Hawera series fluviatile terraces recorded as Us, or stable volcanic rocks (Vo), chiefly Waitearíki Ignimbrite and Minden Rhyolite.

Soils

Almost all of this LUC suite was mapped using soils from the General Survey, excepting only a small area west of the Kaimai Ranges which was mapped using soils from the Piako Survey. The soils recorded are all yellow-brown loams*, from the Katikati, Waitekauri, Whakamarama and Te Manaia sets. The Katikati set was generally recorded on areas closest to the coast, while the other sets occur further inland and are more strongly leached. All these soils, although of low natural fertility, are moderately well-developed compared to

***The Te Puke Survey, not available at the time of NZLRI mapping, covers the area immediately east of the area of the yellow-brown loam LUC suite. In this survey, the Te Puke series, formerly included in the Paengaroa series (composite yellow-brown pumice soil on yellow-brown loam), which is mapped principally in the Te Puke and Maketu districts, has been classified as a yellow-brown loam. In future NZLRI mapping the area of the LUC suite on yellowbrown loams should thus be extended to include the area mapped in this and future soil surveys as Te Puke series, at the expense of LUC subsuite 4a.**

other soils of the region, free-draining, friable and have a moderately high cation exchange capacity. Because they occur in a warm and moist environment, physical conditions for plant growth are excellent. No steepland soils are recorded in this LUC suite because the steepland areas were included in VIIe4 (LUC subsuite 8c).

It should be noted that yellow-brown loams are recorded elsewhere in the region; notably on the Mamaku Plateau and adjacent to Rotorua City (Rotorua Survey), and as hill soils in the Guthrie District (Waiotapu Survey). Yellow-brown loams on the Mamaku Plateau are strongly podzolised, and occur in a sufficiently distinctive climate to justify recognition in a separate LUC suite (5). Others have been included with composite yellow-brown pumice soils on yellow-brown loams in LUC subsuites 7a and 4a. This separation has been made because of the climatic differences between the Tauranga-Te Puke and inland areas and is borne out by agricultural productivity data. This LUC suite is thus distinguished by climate as well as by soils.

Erosion

Erosion was recorded on map units covering 38% of the area of the LUC suite. Only three map units had greater than slight erosion severity recorded, although soil slip on scarps and in hill country may be locally severe. The most commonly recorded erosion types were soil slip, recorded on map units covering 22% of the area, and sheet, recorded on map units covering 14% of the area. Minor types were gully and rill erosion. Most erosion occurred on areas with a dominant pasture cover. Potential erosion on the non-arable LUC units is assessed as moderate, and the erosion associations recognised included associations S on arable land and Q on non-arable land. Soil slip and other associated mass movement erosion usually results from failure at the interface between layers of differently-textured weathered tephras, during short-duration high-intensity rainstorms.

Land Use and Land Management

The present land use pattern is rather varied, due to the versatile soils and the effects of land use diversification, tempered by varied topography. Overall, the predominant present land uses are still pastoral, with dairying being the most important land use at the time of mapping, followed by sheep and cattle breeding and fattening. These land uses occupy nearly 75% of the LUC suite, followed by orcharding, predominantly kiwifruit and citrus. Minor present land uses are exotic forest, maize cropping and market gardening. Undeveloped land occupies about 15%, being mainly small areas of scrub and logged podocarp-hardwood forest interspersed with pasture in the foothills of the Kaimai Range. Many small blocks of exotic forest were mapped in association with pasture and scrub in the hills behind Katikati. Gorse is the main scrubweed.

There is a marked differentiation in both present and potential land use between arable and non-arable land. Dairying and horticultural uses are exclusively concentrated on the arable land while sheep and cattle raising and exotic forestry are on the non-arable land, of which more than 25% is undeveloped.

Land use trends and potentials indicate a clear trend to orcharding on all except the most elevated arable land. Although the potential stock carrying capacity is high to very high, especially for dairying, and exotic forest growth potential is also very high, economic pressures appear to militate against these land uses. Other types of horticulture are also rapidly increasing. The chief soil conservation requirement on the arable land is provision of shelter. However, the recently widespread practice of land recontouring to increase the area of cultivable land (Fig. 29) increases the risk of rill erosion during contouring operations and decreases runoff control, as well as being deleterious to the physical structure of the soil (W.E. Cotching, pers. comm.).

On non-arable land, the potential stock carrying capacity is moderately high and exotic forest growth potential very high. The main trend in land use is expected to be the conversion of cutover indigenous forest and scrub to exotic forest (NWASCO 1982), although small areas around Aongatete Stream, within the Kaimai-Mamaku Forest Park, will probably remain in indigenous forest. Erosion is a continuing risk on much of the non-arable land. Soil

conservation measures include open planting, minimising bare ground exposure and careful stock management on areas adjacent to dissecting gullies (VIIe4, LUC suite 8). Within the LUC suite are three small scenic reserves and a small part of the Kaimai-Mamaku Forest Park, which have high educational and recreational use.

LUC Units on Yellow-Brown Loams (Table **11)**

LUC unit Ilel (3,400 ha)—Figure 9

This LUC unit occurs on flat to undulating land, usually close to the sea and often sloping down into the Tauranga Harbour (e.g., near Katikati). Deep, rhyolitic ashes overlie fluviatile sands and silts although the underlying lithology is relatively unimportant to land use capability. In many other parts of New Zealand, land with this slope would be classified in a V or 'c' LUC subclass. However, in this region, under horticultural use which involves regular cultivation, i.e., other than permanent orchards, there is a continuing slight sheet and wind erosion hazard and potential for rill erosion during high-intensity rainstorms. Land use is either dairying or orcharding, with minor market gardening. Dairying is expected to become a subsidiary land use, and kiwifruit and other subtropical orcharding the major land use, although there is potential for considerably more diversified horticultural use.

LUC unit Illel (4,350 ha)—Figures 9, 10

This LUC unit occurs on undulating to rolling slopes, usually on terraces between 30-100 m a.s.l. Deep Mo' ashes overlie Pleistocene sediments or, occasionally, Minden rhyolite. The slightly steeper slopes of Illel result in a greater potential erosion hazard than for Ilel but it has some advantages over the latter for horticulture and subtropical vines because its rolling slopes and terrace-top position (compared to Ilel which is generally at a slightly lower elevation) allow for cold-air drainage during out-of-season cold spells. It does, however, have a slightly lower potential stock carrying capacity than Ilel. In all other respects Illel is very similar to Ilel. These two LUC units are often either mapped side by side (although separated on the ground by a low scarp) or dissected by fingers of tephric alluvium with a wetness limitation (IIIwl, LUC suite 3). The three LUC units occurring together in close juxtaposition have a very high potential for integrated and diversified horticultural or mixed horticultural/pastoral land use.

LUC unit IVel (7,100 ha)—Figures 9, 10

This LUC unit occurs on rolling to strongly rolling slopes throughout the LUC suite. Many of these slopes occur in the more elevated cooler and wetter parts of the LUC suite, and in places border onto LUC units on the Mamaku Plateau and Kaimai Range. Because of this inland location, IVel is commonly found on rhyolite or ignimbrite as well as on Pleistocene sediments, but soils are very similar to those on Ilel and Illel. IVel has a moderate to severe wind and sheet erosion potential under cultivation, and contains non-arable inclusions. In addition to provision of shelter, arable use should employ contour cultivation. Although dairying and orcharding are by far the dominant land uses, IVel differs from Ilel and Illel in having a greater proportion of undeveloped or partially-developed land. Approximately 15% of its area is covered by cutover hardwood forest or partially-developed pastoral land with pockets of scrub, mainly ***Leptospermum*** or gorse. Nevertheless, the productive potentials are equal to those of Illel and the same general trends in land use can be expected, particularly at lower altitudes.

LUC unit Vcl (650 ha)—Figure 11

This very small LUC unit was mapped on steeply rolling stable hill country to the south-west of Tauranga (on Mindon rhyolite). At more detailed mapping scales it would be more extensively recorded, within the steeper portions of IVel as well as the easier portions of VIel. Apart from slightly steeper and longer slopes, Vcl is very similar to IVel in recorded

TABLE 11: LUC units on yellow-brown loams.

LUC UNIT	IIel	IIIel	VIe2	IVel	Vc1	Viol
PHYSIOGRAPHY	'IIIwl (3) 1 Flat terraces and raised i harbour margins 1	tlwl (3) Undulating | terraces , .1	jvile* I(8c) Moderately steep hill country 1	Rolling terraces Upper terraces	Steeply rolling stable hills	VIIIe3|VIT.e'4 Moderately | (8a) . (8cT) steep stable lyS hills (
AREA (ha)	3 400	4 350	6 850	7 100	650	9 000
SLOPES	A A/B A + B	B/C B + C C	E E/F	C/D C + D D	D/E D	E E + F D + E
SOILS	Katikati (Te Puke)	Katikati Whakamarama (Te Puke)	Katikati Whakamarama Te Manaia	Whakamarama Katikati (Te Puke)	Whakamarama Katikati	Whakamarama Katikati Komata
% MAP UNITS CONTAINING EROSION	0	9	64	15	0	44
PRESENT EROSION	0	ISh	IsSI,Sh	IsSI,Sh	0	ISh,sSI,G
POTENTIAL EROSION	1W,R	0-ISh,R,W	2sSI,Sh,G	2-3Sh,R; 2W,sSI	ISh	2sSI,Sh; 1G
PRESENT LAND USE	Dairying Orchards Fodder cropping	Dairying Orchards Fodder cropping	Sheep & cattle Undeveloped Exotic forestry	Dairying Orchards Indigenous logging Undeveloped	Dairying Orchards	Sheep & cattle Undeveloped Indigenous logging Exotic forestry
STOCK CARRYING CAPACITY (s.u./ha)	17, 23, 28*	15, 20, 23	13, 18, 20	15, 20, 23	13, 18, 20	13, 18, 20
SITE INDEX (m)	38-41*	38-41	32-38*	32-38*	35-38*	32-38*

inventory factors. Although classified as non-arable, it is also similar to IVel in present and potential land use. This is because its dominant arable use is orcharding, by which a permanent ground cover is maintained and little soil disturbance occurs, thus reducing the erosion hazard from that normally expected on arable land. Under pastoral use the erosion risk is negligible and therefore this LUC unit has been assessed overall as having a climatic LUC subclass limitation.

LUC unit VIel (9,000 ha)—Figures 11, 102

This LUC unit occurs on strongly rolling to steep hill country with an almost continuous tephra cover over stable volcanic rocks. It occurs mainly in the inland parts of the LUC suite, especially on the foothills of the Kaimai Range, where it forms the boundary between LUC suites 1 and 8. It is also dissected by steep gullies mapped within LUC suite 8. Like IVel, VIel occurs mainly in a wetter climate than that near the coast, and the dominant soils (Whakamarama and Waitekauri sets) are correspondingly more weathered. The main erosion occurring is slight sheet. Less than 40% of VIel is highly developed for pastoral use, although there is a moderately high pastoral potential. About 30% has an indigenous forest (mainly logged hardwood) cover, and minor indigenous logging occurs. Exotic forestry occurs on a small woodlot scale, but has a high potential and is likely to expand. NWASCO (1982) recommends development of exotic forestry on up to about 30% of VIel and VIe2. Much of this area may come from presently undeveloped land with a scrub cover. Gorse is the main exotic scrubweed. Viel contains small areas of orchards, which is an appropriate land use on easier slopes when a permanent ground cover is maintained. VIel includes 1100 ha on the western side of the Kaimai Range, with brown granular loams and clay soils formed on deep strongly weathered tephras on stable volcanic rocks (Komata series, Piako Survey). This area is generally similar in land use capability to the main part of the LUC suite and has therefore been included with VIel. (See p. 37, footnote).

LUC unit VIe2 (6,850 ha)—Figures 9, 12

This LUC unit occurs on moderately steep hill country on unconsolidated sediments in the Tauranga Basin. Close to Tauranga Harbour, it is also commonly recorded on terrace scarps. In the hills further inland, like VIel it is commonly dissected by gullies. It is slightly more broken than VIel, although a continuous tephra cover has been recorded, and no steepland soils are mapped. The major difference between VIel and VIe2 is the type and intensity of present erosion, which is shown below.

Present erosion	***% area of map units in LUC unit***	
	VIel	VIe2
a) Erosion type:		
Sheet erosion	42	8
Soil slip or gully or streambank erosion	24	76
b) Erosion severity:		
No erosion	43	18
Slight erosion	67	79
Moderate erosion	0	3

In comparison to VIel, VIe2 has more erosion recorded, and this is dominantly mass movement or fluvial erosion. However, potential erosion on both LUC units is assessed as being similar. The present land use pattern on VIe2 is similar to that on VIel but is more intensive because farming has been longer established. There is virtually no indigenous forest remaining, whereas exotic forestry is well established on a farm woodlot scale, both for production and for erosion control. About 30% of the area is low producing pastoral land with partial scrub cover. VIel and VIe2 have similar pastoral and exotic forestry potentials.

F:;.-. ~: i.L'C suite 1: General view of LUC suite in the Tauranga Basin, showing Ilel in foreground, Illel and IVel in midground, and VIe2 on hills in pasture in right background. Steep forested slopes of the Kaimai Range are VIIe4 (LUC subsuite 8c) and steepest parts VIIIe3 and VIIIe4 'LLC subsuite 8a) (eroded portion). S.H.2, south of Katikati district, N57/398739 looking E.

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Fig. 10: LUC suite 1: Illel (foreground) and IVel (background), showing intensive pastoral and orcharding use. Proles Rd, Omokaroa, N58/502622 looking E.

Fig. 11: LUC suite **1:** Stable hill country on Minden Rhyolite. VIel on moderately steep slopes in foreground, Vcl on strongly rolling slopes in midground. Minden district, N58/524556 looking SSW.

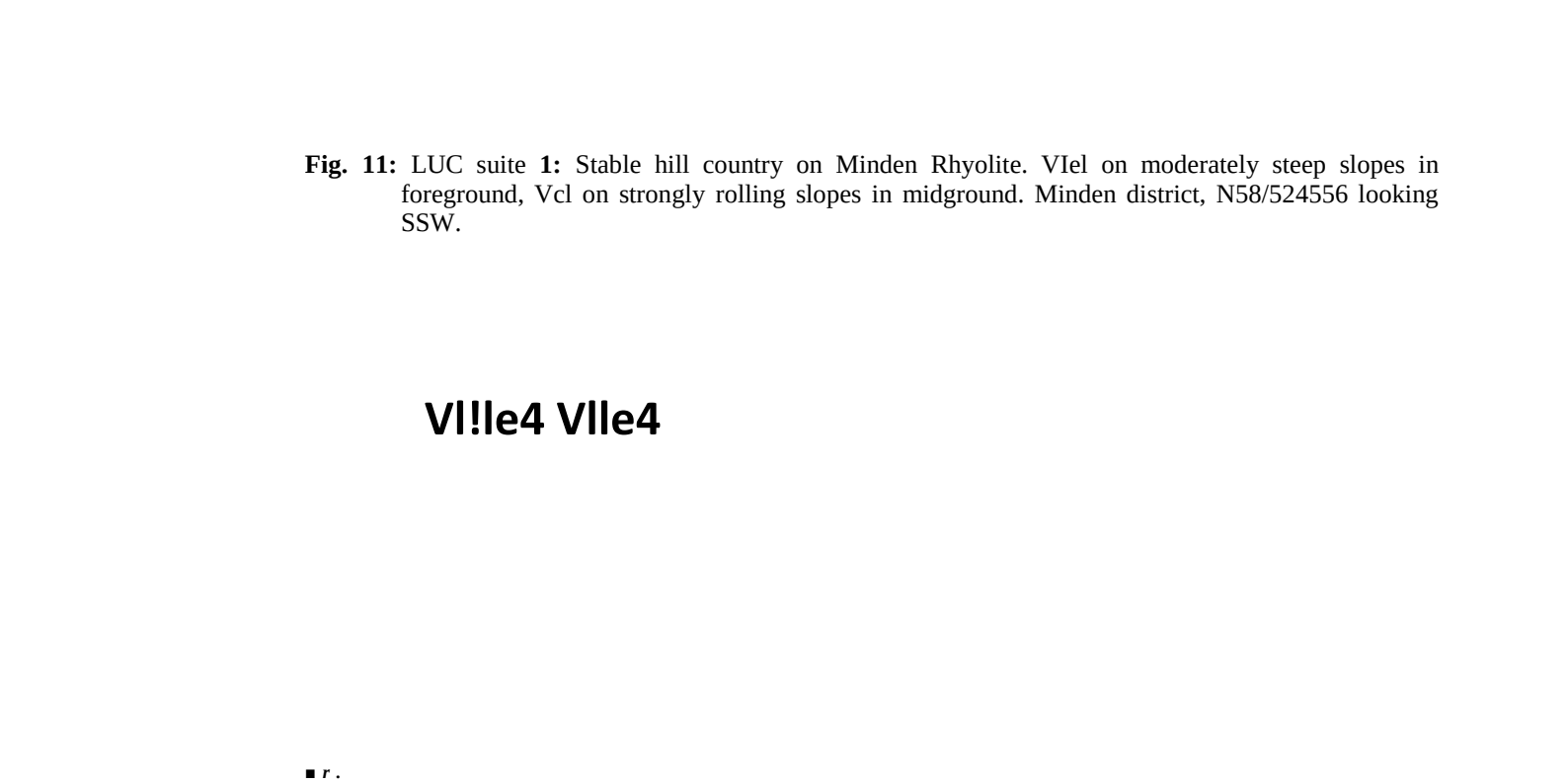


Fig. 12: LUC **suite 1:** VIe2 **on** unstable fluviatile sediments in **Tauranga Basin, subject to soil slip** erosion. Steeper slopes behind are VIIe4 (LUC subsuite 8c) and tops of Kaimai Range at far left are VIIIe4 (LUC subsuite 8a) (Ngatamahinerua). Hot Springs Rd, Katikati district, N57/365716 looking SSW.

LUC SUITE 2: WINDBLOWN SAND

General

This LUC suite is by far the smallest in the region, covering 9300 ha, only 0.5% of the total area of the region. However, the distinctive nature of its parent material warrants the recognition of a separate LUC suite; apart from the steepest ignimbrite and mountain slopes its LUC units are the only ones in which tephras are not the dominant soil-forming parent materials, although they are still thinly present over most of the area.

The LUC suite is confined to the coastal fringe of the Bay of Plenty, and small areas of consolidated inland dune sand on the Rangitaiki Plains near Whakatane (Fig. 8). The sandy coastal fringe, ranging in width from only a few tens of metres near Otamarakau to 3 km near Mount Maunganui, is fairly continuous along the Bay of Plenty, interrupted only at Mount Maunganui, Maketu and at the Whakatane Heads. The sand dunes of this region are continuous with those in the adjacent Coromandel and Eastern Bay of Plenty Regions.

There are three LUC units in this LUC suite: IVs2, VIs4, and VHIel. A related LUC unit is VIwl (LUC suite 3) which is commonly found in small areas of interdune swales with saline soils, although often at too fine a scale to be separately recorded.

Climate

Because this LUC suite is geographically very confined, its climate is fairly uniform, with generally sunny warm maritime conditions. The climate in the west is very similar to that of LUC suite 1. The climate in the east has slightly more variable rainfall. The representative climate station is Tauranga Airport.

Physiography

The coastal dune system comprises foredunes or dune sand of low relief, sometimes interspersed with interdune swales, gradually sloping up to a relatively narrow band of unconsolidated sand dunes of generally medium relief. Between the Kaituna River mouth and Pikowai only the foredune is present, and in places it is too narrow to be recorded as a separate map unit on the worksheets. The whole system displays a complex pattern involving coastal degradation and constant re-working of sand, peat, and airfall and alluvial tephra, especially on the Rangitaiki Plains where buried dunes underlie most of the tephric alluvium and peat which form the modern plains. The dunes occasionally outcrop inland, where they are mantled by thin layers of Tarawera ash, Kaharoa Ash and Taupo Pumice (Pullar & Selby 1971; Pullar ***et al.*** 1978). Overall the dune systems are of fairly gentle topography; nearly 60% of the LUC suite is flat to undulating and about 30% is predominantly rolling to steeply rolling.

Rock Type and Soils

Windblown sand (Wb) was recorded as the only rock type over almost the whole LUC suite, although areas of interdune peat and tephric alluvium are also present, particularly around Matata. As mentioned above, many dunes have a surficial tephric ash deposit, which is usually less than 20 cm thick in total, and therefore rarely mapped as a rock type, but up to 40 cm thick inland.

About 60% of the LUC suite was mapped using soils from the General Survey and the remainder was mapped using soils from the Whakatane Survey. Using only these surveys, soils over nearly 90% of the LUC suite would be classified as yellow-brown sands, and the remainder as composite yellow-brown- pumice soils on podzolised yellow-brown sands (Kopeopeo series, Whakatane Survey).

However, two recent soil surveys not available at the time of mapping (Te Puke and Rangitaiki Plains Surveys) have revealed a considerably more varied soil pattern. On the unconsolidated coastal dunes are recent soils (Ohope or Pikowai series). On the consolidated coastal dunes are composite recent soils on yellow-brown sands (Piripai series), yellow-brown sands (Papamoa series) or podzolised yellow-brown sands (Kairua series). On the inland dunes with a more significant depth of tephra, are composite yellow-brown pumice soils on podzolised yellow-brown sands (Kopeopeo series) or yellow-brown pumice soils (Te Rahu

series). In general, all the soils mentioned are excessively to somewhat excessively drained, with low to moderate natural fertility.

Erosion

Wind erosion was the only type of erosion recognised in this LUC suite. It was recorded on map units covering 45% of the area, almost all of this on the coastal dunes. Map units covering 21% of the LUC suite had slight erosion severity recorded and map units covering 24%, all occurring on unconsolidated dunes, had moderate to very severe erosion. The erosion association over all of the LUC suite is association T. Various parts of the Bay of Plenty coastline have been threatened by dune erosion in the last 30 years. A survey of coastal erosion was undertaken by Healy ***et al.*** (1977).

Land Use and Management

The most important single land use on this LUC suite is dairy farming, either as intensively grazed pastures on the inland areas or as winter runoff on some of the coastal areas. Sheep and cattle rearing is also important. These two land uses account for a little under half of the total area. The other main land use is exotic forestry which occupies most of Matakana Island, and scattered small woodlots elsewhere, comprising about 32% of the LUC suite in total. The remainder of the LUC suite is undeveloped land on the foredunes; this performs an important role in coastal protection and is very heavily used for recreation in summer months. The vegetation on most of this undeveloped land is specialised sand dune associations dominated by marram grass or lupins, but some of the foredunes are bare while other areas have mixtures of rough pasture, lupin, scrub and self-sown or small woodlots of pine trees. These areas of pine trees occur particularly in the partly urbanised area between Mount Maunganui and Papamoa. A minor use on the low inland dunes (IVs2) is horticulture, mainly kiwifruit and horticultural crops suited to sandy soils, e.g., asparagus. A small amount of maize cropping also takes place.

No major changes in the land use pattern are envisaged. Most of the presently undeveloped land is LUC class VIII land on the foredune, where no active use is recommended. Although both of the other LUC units have medium to high forest growth potentials, they also have a moderately high to high potential stock carrying capacity. This potential is at present largely unrealised and is especially valuable in dairying systems as a complement to adjacent areas on more fertile but poorly drained soils. The main limitation to agricultural use is the drought-prone, excessively drained soils; it is estimated that in about one year in four, soil moisture levels in coastal dune areas are deficient for pasture growth over 60% of the growing season (Pullar ***et al.*** 1978). These soils are also prone to grass grub and black beetle infestation. Productivity could be increased by irrigation and increased use of lucerne.

LUC Units on Windblown Sand (Table 12)

LUC unit IVs2 (4,900 ha)—Figure 13

This LUC unit occurs on gently undulating to undulating fixed dunes, both inland and near the coast. It is the only LUC unit in this LUC suite to occur on the inland dunes, or to have significant (although variable) amounts of tephric ash mantling the windblown sand. Soils are therefore varied, and are podzolised in places. Map units covering 37% of the LUC unit are affected by slight wind erosion, with a potential for slight to moderate wind erosion under cultivation. The present land use pattern could be expanded to include root and green fodder cropping, cereal cropping, and further specialised horticultural crops. These areas could be concentrated where more peaty and fertile soil phases occur, e.g., Kopeopeo and Te Rahu loamy sand (Whakatane Borough and Rangitaiki Plains Surveys). However, all arable uses require the provision of shelter and are still subject to limitations of low soil fertility, soil moisture deficits and a continuing erosion risk under cultivation. Because of these limitations, and the high potential stock carrying capacity, intensification of pastoral management would seem to be the most suitable long-term land use over most of this LUC unit.

TABLE 12: **LUC units on windblown sand.**

LUC UNIT	1VS2	Vls4	Vlle 1
rSrflBTucljNiT (LUC Suite) PHYSIOGRAPHY	Inland dunes (low relief)	' IIIwl etc' 1(3) | lAlluvial 1 Fixe jplains | di	2d coastal jnes	VIwl (3) Inter - dune swale	Foredunes |Sea
AREA (ha)	4 900		2 350		2 100
SLOPES	A/B B B/C		D + C C + B B + C		D + C F + C
SOILS	Kopeopeo Te Rahu (Papamoa) (Kairua)		Pxripai (Papamoa) (Kairua)		Pinaki Pikowai (Ohope)
% MAP UNITS CON-TAINING EROSION	22		0		0
PRESENT EROSION	1W		0		2-4W
POTENTIAL EROSION	0 (1W)		1W		5W
PRESENT LAND USE	Dairying runoff Cattle & sheep Exotic forestry Horticulture		Cattle & sheep Undeveloped		Undeveloped Extensive grazing
STOCK CARRYING CAPACITY (s.u./ha)	12, 15, 21*		11, 15, 16*		-, o
SITE INDEX (m)	25-30		25-30		0

LUC unit **VIs4 (2,350 ha)—**Figure 13

This LUC unit occurs on undulating to strongly rolling consolidated coastal dunes behind the foredunes. Behind Papamoa Beach it occurs as a complex with IVs2. VIs4 does not have a significant tephric ash cover, soils being yellow-brown sands (Piripai and Papamoa series), podzolised in places (Kairua series). No present erosion is mapped, and under non- arable use a potential of only slight wind erosion is recognised. However, compared with IVs2, the greater slope and shallower soils of VIs4 increases its susceptibility to drought and drought-related pest problems. The main land use on VIs4 is extensive grazing, although it has a significantly lower potential stock carrying capacity than IVs2. Exotic forestry would be an appropriate land use. However, its proximity to the residential areas of Mount Maunganui-Papamoa Beach and Whakatane will largely dictate land use. Where pastoral use occurs, a complete vegetative cover should be maintained to protect against wind erosion, while forest management should comply with the "Forest Operations" guidelines (NWASCO 1978).

LUC unit **Vlllel (2,100 ha)—**Figures 14, 24

This LUC unit is mapped on unstable sand dunes with an extreme erosion potential. It occurs along almost the entire Bay of Plenty coastline, up to 0.75 km inland. Soils occurring on Vlllel are mainly recent (Ohope and Pikowai series), with some inclusions of composite recent soils on yellow-brown sands (Piripai series). Slopes are variable, mainly steeply rolling and rolling but including short steep dune slopes. There is moderate to very severe present wind erosion and extreme potential erosion. The vegetation mainly comprises sand dune associations dominated by marram grass or spinifex, although much of the LUC unit is covered by bare sand. Some minor (and probably uncontrolled) grazing occurs, but Vlllel is unsuitable for either pastoral or production forestry use. Where coastal integrity is threatened by dune erosion, stabilisation measures may be required, either by engineering works or by sand stabilisation followed by protection forestry planting. Urban residential development is generally undesirable because of the high risk of coastal erosion.

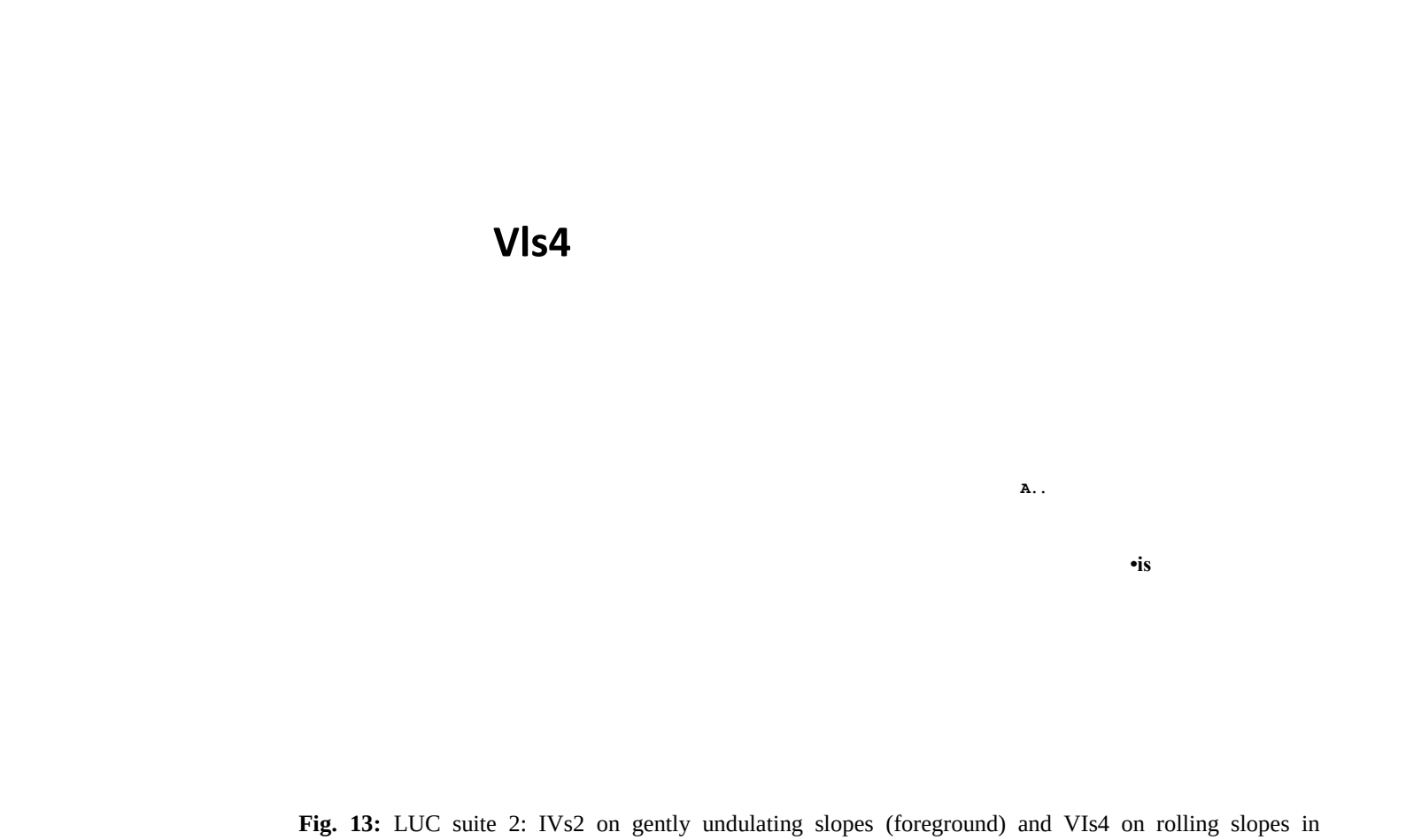


Fig. 13: LUC suite 2: IVs2 on gently undulating slopes (foreground) and VIs4 on rolling slopes in background, on windblown sand, subject to sheet erosion under pastoral use. Papamoa district, N58/780556 looking S.

Fig. 14: LUC suite 2: Vlllel on coastal foredune. Pokare Beach, Pukehina, N68/027433 looking SE

LUC SUITE 3: ALLUVIUM

General

This LUC suite is characterised by a soil parent material consisting dominantly of tephric alluvium, i.e., alluvially redeposited volcanic material. Peat formation is also widely associated with this alluvium. Wetness is the dominant subclass limitation, except on the more free-draining terraces.

This LUC suite is the most widely dispersed in the region, occurring on lowland flood plains, lake edges and river valleys throughout (Fig. 8 and 55). However, more than 70% of its area is concentrated in the Bay of Plenty lowlands. These areas contain the most fertile soils in the region and have a favourable climate for primary production. As a result, this LUC suite contains much of the most versatile land (70% of all LUC class I and II land), and has been highly modified and developed.

The area of the LUC suite is 72,550 ha, 4.1% of the total area of the region. There are ten LUC units: Iwl, IIwl, IIIwl, IVwl, VIwl, VIIIwl, IIs2, IIIs3, IVs3 and IIIcl. The six LUC units with a 'w' (wetness) subclass form a continuum of degree of gleying and increasing overall wetness limitation. The other four LUC units are more variable in their type of limitation.

Although the LUC suite is not divided into subsuites, the LUC units fall roughly into two groups: Iwl, IIwl, IIs2, most of IIIwl, and VIwl occur mainly close to sea level in coastal Bay of Plenty, while IIIcl and IIIs3 occur exclusively inland and IVwl, IVs3 and VIIIwl predominantly so. They have been grouped in this way in the summary tables (Tables 13a, b). However, several of the LUC units occur in both situations.

Being widely dispersed along river valleys, lake margins, etc, small areas of land in this LUC suite often occur within other LUC suites and subsuites, notably 1, 4a, 7a and 7f (Fig. 8, 55).

Climate

The climate over this LUC suite is varied. In the coastal Bay of Plenty portion it is similar to **that** described for LUC suites 1, 2 and 4, i.e., rainfall between 1300-1500 mm annually and mild temperatures with few frosts. Much of the LUC suite in this area is subject to extremes of soil moisture, i.e., summer deficits as well as winter excesses caused by poor natural drainage of most soils. Representative climate stations are Te Teko, Whakatane, Te Puke and Tauranga. Areas further inland tend to be slightly cooler in winter and slightly wetter. The climate in the Reporoa basin is distinctive because of cool frosty winter temperatures and foggy conditions in winter and autumn. Climate in other areas of the LUC suite, e.g., Taupo, Galatea and Rotorua districts, is summarised in other sections (see for example LUC subsuites 4b, 7a, 7f).

Physiography

The Rangitaiki Plains, situated in the Whakatane Graben between two prominent north-south aligned fault scarps, consist of a complex series of sand ridges with intervening peat swamps, all partly buried by layers of recent volcanic alluvium. They have built up over the last 9000 years, during which time the coast has episodically prograded approximately 9.75 km. Floodplain sediments were supplied by the Tarawera and Rangitaiki Rivers and consisted mainly of tephra from these catchments, together with some greywacke alluvium from the Kaimanawa and Ikawhenua Ranges. The system has been described by Pullar & Selby (1971).

The Te Puke and Maniatutu Plains, lying in the Maketu Basin and divided by the Maketu promontory (LUC subsuite 4a), are also formed from volcanic material transported by the Kaituna River and the various streams and canals draining into the Waihi Estuary. These plains are bounded by dune sands. Because their sediment-supplying catchments have been mantled by less tephra in the last 7000 years than those supplying the Rangitaiki Plains, their rate of accumulation and progradation has not been as rapid, so that they are lower lying and have greater amounts of peat.

The Reporoa Basin is a tectonic basin filled with various breccias and sediments, and showing lacustrine features dating from two periods in the last 20,000 years when lakes occupied the basin (Pain & Pullar 1975). Areas of this LUC suite in the basin are formed on post-Taupo surfaces of reworked Taupo Pumice exposed after the second lake receded. Some peat formation has also occurred.

Other areas scattered through the region occur on recent alluvial or lacustrine sediments of various tephric materials. These are described as post-Kaharoa floodplains in the Whakatane (Pullar ***et al.*** 1968) and Waimana Valleys, as lake shore, alluvial terrace and alluvial valley fill deposits around Lake Rotorua (Kennedy ***et al.*** 1978), and as fans on post-Kaharoa surfaces and recent (post-Tarawera) floodplains in the Galatea Basin (Pain & Pullar 1968). Around Lake Taupo and Lake Rotoaira the surfaces on which the LUC suite occurs are all of recently reworked Taupo or Ngauruhoe ashes, as opposed to older materials in the Bay of Plenty sector of the region. Almost all land in this LUC suite is flat or nearly so, occasionally dissected by stream channels.

Rock Type and Soil Parent Material

Because most of the alluvium in the region is either derived from Taupo Pumice or younger tephras, or is derived from older material which has been redeposited since the time of the Taupo Pumice eruption, it is by definition regarded as recent volcanic alluvium (Tp) rather than undifferentiated floodplain alluvium (Al). However, greywacke and sedimentary rocks have also contributed to the source material. Tp is recorded as the only rock type over 70% of the LUC suite; it is also recorded locally in combination with various other rock types.

Because volcanic alluvium derived from Taupo flow or water-sorted tephra is also a parent material in another widespread LUC sub suite, 7f, there is inevitably some overlap between that subsuite and LUC suite 3. This will be discussed under the various LUC units.

The other important parent material is peat (developed on volcanic alluvium). It is recorded either on its own or together with Tp over about 25% of the LUC suite. It was undermapped in the southern Rangitaiki Plains, compared with the area mapped by Pullar & Selby (1971) and in the Rangitaiki Plains soil survey.

Other soil-forming materials are localised in occurrence: for example, on the Rangitaiki Plains windblown sand is occasionally recorded as an underlying or minor rock type, while the southern, older portion of the Rangitaiki Plains is mantled with Tarawera ash which is recorded as a surficial rock type on small areas. Greywacke gravels are recorded in the Galatea Basin.

Soils

A little over 50% of the LUC suite was mapped using soils from the Whakatane Survey, and about 25% using soils from the General Survey. Over the remaining area, small areas of soils from all other surveys in the region were recorded. The need to use this large number of soil surveys has complicated comparison of soils information. Also, a large number of soil series are recorded in several of the LUC units, because physiographic position and degree of limitation were more important than soil parent material or soil type in making the LUC assessment. However, three major soil groupings occur:

1) The largest is the grouping of gley, gley-recent (or gleyed recent) and recent from alluvium soil groups, which occur on about 60% of the area of the LUC suite. They are formed from undifferentiated alluvium and show limited profile development. Small areas of these soils have saline influence (saline gleyed recent soils).
2) Organic soils from peat, which occur on about 25% of the LUC suite.
3) Where slightly older alluvium is mantled by thin Kaharoa or Tarawera ashes, yellow-brown pumice soils and composite recent soils on yellow-brown pumice soils are recorded. These soils are discussed further in LUC units IIs2, IIIcl and IIIs3. The grouping occupies about 15% of the LUC suite and occurs on LUC units whose dominant limitation is not wetness.

The first two groupings, which form a continuum, contain the most fertile soils of the region and usually occur on flat land, so that their major limitation arises out of their drainage characteristics.

Erosion

There is little recorded erosion on this LUC suite. Streambank erosion was the only significant erosion recorded, occurring on map units covering 16% of the LUC suite. Recorded erosion was usually of minor severity although it may be more severe locally. Sheet and gully erosion was recorded on a few map units, and deposition occurs frequently after flooding but was only recorded in the Galatea Basin.

Land Use and Land Management

Most of the land in this LUC suite is highly developed and there is a smaller proportion of undeveloped land than in any other LUC suite in the region. Intensive pastoral use, mainly for dairying, is the major land use (more than 80% of the area). About 10% is used for cropping, the most important arable crop being maize on the Rangitaiki Plains and in the Whakatane River valley. There is also a diverse range of horticultural crops including kiwifruit and citrus orchards. Although NZLRI mapping specifically excludes urban areas, most of the urban areas in the Bay of Plenty occur wholly or partly within this LUC suite, and future expansion will inevitably occur and include some of its most versatile land.

Less than 10% is undeveloped, most of this being wetlands reserved for recreation, wildlife or water retention purposes. They are mainly dominated by willow trees, but small areas are covered by bog or swamp associations, manuka, gorse or blackberry, or, in saline areas near the coast, salt-tolerant plant associations.

Dairying is likely to remain the mainstay of land use, but because all arable units have relatively fertile soils and a favourable climate, there is considerable potential for diversification. Maize cropping at present predominates over horticulture but this trend may reverse as the former becomes confined mainly to the soils most suitable for it and horticulture increases elsewhere. Horticultural intensification will, however, be dependent on improved drainage, as well as the provision of shelter from prevailing winds.

Drainage capacity will remain the main limitation to arable and pastoral use; existing schemes leave surficial ponding after rainfall of a 5 year or greater return period. The effects of drainage on specific areas is difficult to predict, particularly on areas that are marginally arable, and this has lead to difficulties in the assessment of the total degree of limitation, and the consistent delineation of LUC class along the continuum of the wetness limitation. Many of these coastal lowland areas have a seasonally fluctuating water table and would also benefit from irrigation during the summer dry period. Special care should be taken not to over-drain peaty soils because this leads to loss of soil structure as well as increased susceptibility to summer drying.

Flood protection is presently provided for 100-year flood levels on the Rangitaiki and Kaituna Rivers. Comparable flood protection on other areas is an important requirement, with streambank planting and/or groyne construction also necessary in some areas to restrict or retard streambank erosion. Forestry is a very minor land use because of the traditionally high value of the agricultural production. But because forestry potentials are medium to very high on the more versatile land, production forestry may show a slight expansion in areas that do not have a predominant wetness limitation, principally in the Galatea Basin. Finally, the retention of some of the last wetland remnants in the region would be desirable, both for water retention for flood protection schemes and for wildlife conservation.

LUC Units on Alluvium (Table 13a, b)

LUC unit **Iwl (2,850 ha)—**Figure 16

This LUC unit consists of flat to gently undulating river levees and terraces with naturally fertile recent soils and with only a very slight wetness limitation remaining after drainage. It occurs on slightly raised areas beside the Rangitaiki and Whakatane Rivers, which are more free-draining and have a lower risk of surface ponding than other areas on the plains.

TABLE 13a: LUC units on alluvium

a) coastal Bay of Plenty.

LUC UNIT	IIw1	IIIw1	IIs2	IIIwl	IVwl	Vlw1
RELATED LUC UNIT (LUC Suite)				Illel (1) | 1		IviIIwl |
PHYSIOGRAPHY	Increasing wetness limitation River levee	Flood plain	Flood plain with ash cover	Terracel Flood plain anc river valley	Swampy flood plain/river valley	Saline swamp and lake swamp |River
AREA (ha)	2 850	19 350	9 450	15 250 +	3 750t	1 450
SOILS	Awakaponga	Pongakawa	Awaiti	Pongakawa	Rangitaiki	Takahiwai
% MAP UNITS CONTAINING EROSION	Opouriao 0	Paroa Otakiri Onepu 5	Opouriao Awakeri Te Teko 0	Rewatu Kairanga (Parton) 2 2 +	Otakiri 20 +	Meeanee-Farndon Otakiri (Muriwai) 0
PRESENT EROSION	0	lSb	0	1-2Sbt	lSb+	0
POTENTIAL EROSION	0	0	1W(1W)	lSb(lSb)+	lSb(lSb)+	0
PRESENT LAND USE	Dairying Cereal cropping Orcharding Horticulture	Dairying Cereal cropping Orcharding Horticulture	Cereal cropping Dairying Sheep & cattle Orcharding	Dairying Sheep & cattle Cereal cropping Undeveloped	Dairying Undeveloped	Undeveloped Extensive grazing
STOCK CARRYING CAPACITY (s.u7ha)	15, 24, 29	18, 22, 27	19, 27, 32	16, 19, 24t	8, 11, 15+	10*, 12*, 14*
SITE INDEX (m)	35-36	30-31	40-41	25-26t	0 +	0

tApplies to whole.LUC unit (see following tabic).

TABLE I3b: l.l[·]C units on alluvium
b) inland Areas.

LUC UNIT	IVs3	IIIs3	IIIcl	IIIwl	IVwl	VIIIwl
			RELATED LUC UNIT (LUC Suite)		IIIs4 i(7h)	
					Increasing wetness limitation ■	
PHYSIOGRAPHY	Floodplain of inland river					
	Low alluvial terraces	Ash-covered terrace				
	Post-Taupo surface in Reporoa Basin					
	River valleys Lake edges					
	Lake - edge swamp					
		Kaingaroa Plateau				
PRESENT LAND USE	Sheep & cattle Dairying Undeveloped Exotic forestry					
AREA (ha)	10 750	4 600	2 150	15 250+	3 750 +	20+
SOILS	Rangitaiki	Rangitaiki Whakatane Horomanga	Wharepaina Tokaiminga	Reporoa Mokai Utuhina Ngongotaha	Tokaanu Mokai Oturere	
% MAP UNITS CONTAINING EROSION	40	15	11	22 +		
PRESENT EROSION	lSb,D	lSb	lSb	lSb(lSb)	l-2Sb+	lSb+
POTENTIAL EROSION	2Sb,D(2Sb,D)		ISb(lSb)	lSb(lSb)+	!Sb(lSb)+	Undeveloped Dairying Extensive grazing
			Dairying	Dairying Cereal cropping Exotic forest	Dairying Sheep & cattle Undeveloped	

2 950	Tokaanu Turangi	17	1Sb	Undeveloped
		1Sb		
STOCK CARRYING CAPACITY (s.u./ha)	15, 19, 25	•, -, 0		
SITE INDEX (m)	37-41			
	15, 20, 24			
	35-41			
	15, 20, 25			
	33-35			
	16, 19, 24+			
	25-26+			
	8, 11, 15+			
	0 +			

tApplies to whole LUC unit (see previous table)

These areas are also protected by flood control schemes. These advantages, combined with favourable climate and soils of high natural fertility, result in the very high versatility of this the only LUC class I unit in the entire region. Soils of the levees (Opouriao and Orini series, Rangitaiki Plains Survey) could be regarded as the elite soils of the region. Iwl also includes some recent soils on associated backswamp lowlands (Awakaponga series). These soils are peaty and have imperfect to poor natural drainage but are included in Iwl because they can easily be drained and frequently occur in association with Opouriao soils at the scale of mapping.

All of Iwl is developed for intensive dairying, cropping and horticulture. At present maize cropping is the predominant arable use, but horticulture will continue to expand at the expense of both cereal cropping and dairying. Iwl is frequently managed in conjunction with IIwl.

LUC **unit IIwl** (19**,350 ha)—**Figures 15, 16, 27

This LUC unit consists of flat plains in coastal Bay of Plenty, with fertile soils that have a moderately high winter water table and a slight wetness limitation after drainage. It is most extensive on the Rangitaiki Plains, where it is the predominant LUC unit, occupying about 50% of the total area. It also occurs on the fringes of the Tauranga Harbour (in association with Ilel and Illel, LUC suite 1), on the Te Puke and Maniatutu Plains, and in the lower Whakatane River valley.

On the Rangitaiki Plains and Whakatane River valley IIwl occurs on recent and gley-recent soils on former flood plains and backswamp lowlands. These soils have imperfect to poor natural drainage; under present drainage capacity, ponding will occur under a 5 year maximum rainfall and may remain for up to 72 hours (N. Ngapo, pers. comm.). This slightly limits versatility for arable use, but with improved protection from surface flooding much of this area could be reclassified as Iw. On the Te Puke and Maniatutu Plains, IIwl has been mapped on more peaty parent material occurring in drained swamps and on former floodplains. Soils are recent and organic and are often gleyed. In some cases artificial drainage has been installed or is planned*.

The predominant present land use on IIwl is intensive dairying and maize cropping, but rapid diversification towards horticulture is occurring. A very high potential stock carrying capacity, and generally high cropping and horticultural potentials (apart from the exceptions discussed in footnote below), indicate the scope for diversification. Forest site indices have also been assessed as high but, because of the versatility of IIwl for food production, exotic forestry is likely to remain an insignificant land use. Some recent soils recorded in IIwl are unsuitable for exotic forestry.

LUC **unit IIs2** (9**,450 ha)—**Figures 15, 17, 20

This LUC unit occurs on areas of the lowland plains which have a thin mantle of Tarawera and Kaharoa ashes overlying tephric alluvium. Soils on this LUC unit have coarser-textured upper horizons and are more susceptible to periods of summer soil moisture deficiency than those on adjacent areas without the airfall mantle. IIs2 occurs in the southern and western parts of the Rangitaiki Plains. These are older parts of the flood plain where accumulation ceased before the Kaharoa and Tarawera eruptions, and hence have a shallow mantle of these ashes. IIs2 also occurs on flat river terraces in the lower Whakatane and Waimana valleys.

The rock type recorded over most of IIs2 was tephric alluvium (Tp) because Tarawera ash was thick enough to be recorded in the rock type inventory over only 16% of the area and Kaharoa Ash not at all. Soils recorded over 45% of the LUC unit are classified as composite recent soils on yellow-brown pumice soils (Awaiti and Te Teko series). These

***These areas were mapped using the General Survey. However, in the recent Te Puke Survey the gley and composite gley on organic soils, principally Pongakawa, Parton, Raparahoe and Ohineangaanga series, have generally been ranked lower for food production than neighbouring yellow-brown loams and well-drained recent soils. Although many of these former swamp soils have a very high potential stock carrying capacity for dairying, a continuing wetness limitation after drainage and fluctuating groundwater levels gives them a lower potential for arable use and lower overall versatility than the soils included in IIwl on the Rangitaiki Plains. Much of the Te Puke and Maniatutu Plains would therefore more appropriately be reclassified as IIIw in future**

soils have a thinner mantle of Tarawera ash, a more varied parent material, and are finer-textured than other soils formed on Tarawera ash. For this reason, IIs2 is included in this LUC suite rather than in the Tarawera LUC subsuite (6c). All soils mapped in IIs2 are subject to the same wetness limitation as those in IIwl*; however, the slight wetness is regarded as being overridden by the limitation of summer drought risk.

In the valleys of Whakatane and Waimana Rivers the parent materials and soils of IIs2 differ from those described above. Here there is no ash mantle and the soils are classified as recent (Opouriao series). On the Rangitaiki Plains these soils are included in Iwl but the river valleys have a slightly greater risk of flooding, and slightly cooler temperatures (with occasional air frosts), and have therefore been classified as LUC class II. Because the Opouriao soils are free-draining they have been included with IIs2.

IIs2 has no present erosion, and only a slight wind erosion potential when cultivated. Predominant land uses are dairying and maize cropping, with minor areas used for sheep and cattle raising, orchards, farm woodlots, and nurseries. The present land use pattern is fairly close to that recommended in NWASCO (1982), i.e., 70% dairying and 30% horticulture. Maize yields in the Te Teko and Taneatua districts are among the highest in New Zealand, and both the potential stock carrying capacity and forestry site index are the highest in the region; overall versatility is limited only by a slightly decreased horticultural versatility due to the factors discussed above.

LUC unit **IIIwl (15,250 ha)—**Figures 15, 18, 28

This LUC unit occurs throughout the region on poorly drained flats, low terraces with a high water table, and in enclosed valley bottoms subject to runoff from adjacent hills. It is probably the most widespread LUC unit in the entire region, being extensively recorded on the Rangitaiki, Te Puke and Maniatutu Plains, in the Whakatane and Waimana valleys and many other smaller river valleys in the Bay of Plenty. Inland it occurs around Lake Rotorua, in the Reporoa and Ngakuru Basins and the King Country. It also occurs throughout the region in many poorly drained areas too small to map at the scale of the NZLRI.

Volcanic alluvium or peat is generally recorded as the rock type. The majority of the soils are classed as recent or organic, usually gleyed. Most soils have very poor natural drainage but can be successfully drained so that wetness becomes only a moderate limitation to arable use. IIIwl is occasionally dissected. Minor streambank erosion is common and is occasionally recorded at moderate severity. Pole planting along streambanks is the main soil conservation measure required.

Dairying is by far the major land use. Minor cereal cropping is practised on the Rangitaiki Plains, and horticultural use is scattered throughout, especially orcharding in the Tauranga- Te Puke district. However, in this district IIIwl is much less suitable for horticulture than is the surrounding terrace land (LUC suite 1 and subsuite 4a), not only because of poor drainage but also because of cold-air drainage from the terrace tops into the intervening valley bottoms which results in much heavier losses of sub-tropical crops during cold spells. Approximately 3% of the LUC unit is undeveloped, with frequent small areas of rushes or swamp vegetation throughout.

Because of its generally high fertility and relatively high water table, even during dry spells, IIIwl has a very high potential for dairying when drained, and this is the main recommended land use. Its potential for most other uses is much lower, and its cropping versatility may be further restricted by the wetness limitation delaying planting or limiting access at harvesting. Exotic forestry growth potential has been ranked only as medium (although IIIwl may be well suited to some specialist timber species which are better suited to poorly drained soils than is ***Pinus radiata).*** Despite these limitations, however, in some predominantly hill country areas IIIwl is the only arable land on individual farms and as such offers valuable opportunities for diversification.

,*In particular the Awakeri soils were classified as an imperfectly drained gleyed recent soil, and have since been separated (Rangitaiki Plains Survey) into a loamy sand and a sandy loam. The former is regarded as very poorly drained and would probably be reclassified as IIIw in future remapping.

LUC **unit IIIcl (2,150 ha)—**Figure 21

This LUC unit occurs on flat to gently undulating areas in the Reporoa Basin that have well-drained peaty soils formed on Taupo volcanic alluvium, and where the dominant limitation to arable use is a cool winter climate. At the scale of mapping of the NZLRI, IIIcl is closely associated with IIIwl and IVwl (this LUC suite) and with IllelO (LUC subsuite 7f). It is difficult to distinguish between these LUC units in this district, because several soil types are common to more than one LUC unit, and because IIIcl has significant areas of yellow-brown pumice soils recorded (Wharepaina series) as well as organic and recent soils (Tokiaminga and Reporoa soils). However, the natural drainage of IIIcl is poorer than on IllelO so that peat formation occurs; this is the main reason that IIIcl is included in LUC suite 3 rather than LUC subsuite 7f. The drainage on IIIwl and IVwl is poorer still.

Present land use on IIIcl is almost exclusively dairying with minor winter fodder cropping. Dairying potential is high, and because the extended cold and foggy winter restricts cropping potential, an exclusively dairying land use was recommended in NWASCO (1982). However, a restricted range of cereal and horticultural crops could be grown. Forestry potential is ranked as high but would be medium on the organic soils.

LUC **unit IIIs3 (4,600 ha)—**Figure 22

This LUC unit occurs on low river terraces which have recent alluvial soils formed dominantly from redeposited Kaharoa Ash mixed with other alluvium. It occurs in the lower Whakatane valley between Taneatua and Waikirikiri, the lower Waimana valley around Waimana settlement, and the eastern Galatea Basin. In the first two areas it occurs mainly on post-Kaharoa low terraces of recent alluvium (soil recorded as Rangitaiki fine sandy loam) and in the third area it occurs on pre-Kaharoa surfaces where Kaharoa Ash is overlain by more recent flood outwash from the Ikawhenua Range (Horomanga series). In both cases the soils are classified as recent soils from alluvium and have a finer texture, higher water table, and better structure and moisture holding capacity than surrounding soils formed on coarser materials (Rangitaiki gravelly sand and Galatea sand, occurring on IVs3 (LUC suite 3) and IIIs4 (LUC subsuite 4b) respectively). In all three LUC units the dominant limitation to use is seasonal soil moisture deficits. IIIs3 and IIIs4 are very similar, both being derived predominantly from Kaharoa Ash, but IIIs3 is only mapped where the ash has been redeposited. IIIs3 also includes areas in the Waimana valley where yellow-brown pumice soils (Whakatane sand) are mapped; these areas would probably have been better included in IIIs4.

IIIs3 is predominantly used for dairying but there is some diversification to cereal cropping and exotic forestry, and there is potential for considerable intensification of pastoral use. It also has a very high exotic forestry potential. Areas of the LUC unit occurring in the very sheltered lower valleys of the Whakatane and Waimana Rivers have good horticultural potential if irrigated.

LUC **unit IVs3 (10,750 ha)—**Figures 20, 22, 101

This LUC unit occurs on flood plains and fans with coarse or stony textured soils which have low natural fertility. It is widely distributed on the lower levels of major river valleys in the eastern Bay of Plenty. It also includes some bouldery fans on the eastern Galatea Plains. Alluvium or gravel, predominantly derived from greywacke, was equally as important as volcanic alluvium in the rock type inventory. As with IIIs3, there are considerable amounts of Kaharoa Ash in the soil parent material; these two LUC units are distinguished largely on soil texture.

Potential stock carrying capacity was assessed as being as high as for IIIs3 but the value given is believed to be an overestimate. Pastoral use occupies about 60% of the LUC unit. Exotic forestry also has a very high potential, and this would be a suitable land use for much of this LUC unit except for some areas where water tables are high. These potentials do not apply to the river channels or immediate environs which are subject to regular flooding, and which at detailed mapping scales would either be excluded (river channels) or separated as LUC class VII or VIII. Many of these areas, at present supporting willow growth, have a high value for wildlife conservation and recreation. Streambank protection is a necessary soil conservation technique because IVs3 has much more streambank erosion recorded than any other LUC unit in the LUC suite. Minor deposition also occurs.

LUC **unit IVwl (3,750 ha)—**Figures 15, 19, 20

This LUC unit occurs on low-lying river flats and lake margins where drainage is difficult and there is an occasional surface flooding risk. It occurs in both coastal and inland districts, the largest areas being on the margins of the Rangitaiki Plains and on the southern shores of Lake Taupo near Turangi. Other areas are scattered throughout coastal districts, alongside the Whakatane River and in the Reporoa and Ngakuru Basins.

IVwl is mapped mainly on volcanic alluvium or peat. In the southern Rangitaiki Plains it is mantled by thin Tarawera ash. Soils are dominantly gleyed recent or organic soils. Ivwl is sometimes dissected, and minor streambank erosion is recorded. About 50% of its area is dominated by improved or unimproved pasture, sometimes with minor scrub such as gorse or blackberry, occasionally with minor winter fodder crops inland, and commonly with minor rushes or swamp associations. Those areas without a dominantly pasture cover have mainly wetland vegetation.

The land use pattern is dominated by dairying, but to a lesser extent than on IIIwl. Some sheep and cattle grazing occurs. Dairying use is capable of considerable intensification after drainage but arable potential is extremely limited because of a continuing flooding risk and wetness limitation. In general IVwl is unsuitable for production forestry. Its versatility is thus considerably restricted compared with IIIwl. Most presently undeveloped areas will probably remain as wetland reserve and water retention reserves under flood protection and drainage schemes (NWASCO 1982).

LUC **unit VIwl** (1**,450 ha)—**Figure 23

This LUC unit occurs on low-lying coastal areas with a very high water table, which are subjected to frequent flooding even after drainage. It has a restricted distribution, being scattered in Bay of Plenty coastal areas between Tauranga and the mouth of the Rangitaiki River. It is distinguished from IVwl by a coastal saline influence, having predominantly gleyed saline recent soils. The soil parent material recorded is peat and volcanic alluvium.

The vegetation over 70% of VIwl comprises mixtures of improved and unimproved pasture and wetland or salt-tolerant vegetation. Over the rest the vegetation is dominated by willows or swamp vegetation. Land use is fairly similar to that on IVwl but with a greater amount of undeveloped land. Pastoral use is restricted by pugging and salinity problems so that careful management is essential to make full use of the limited pasture production possible. VIwl is unsuitable for forestry.

LUC **unit VIIIwl (2,950 ha)—**Figures 24, 84

In this LUC unit the sequence of increasing wetness limitation rises to its maximum and is assessed as severe and permanent. It is scattered in coastal, lakeside and riverine areas throughout the region, but its largest extent is on the southern shores of Lake Taupo. Over much of its area, it occurs on Taupo flow tephra, with rock type recorded as Tp, but there has been extensive peat formation and most soils are classified as organic (principally Tokaanu series). Very occasional streambank erosion is recorded, but the erosion potential is regarded as insignificant to slight and this is the main difference between this LUC unit and IIIw2 (LUC subsuite 7f).

In general VIIIwl is undeveloped and has a wetland vegetation cover, usually swamp associations or willows with some minor manuka scrub. Salt-tolerant associations and mangroves are recorded in a few coastal areas. Because it is so low-lying, drainage of this LUC unit is usually not feasible.

lis2

! W 1

Vw1

Fig. IS: LUC suite 3: General view across south-western Rangitaiki Plains in vicinity of Tarawera River mouth, showing IVwl near lagoon (right foreground), IIIwl downstream from lagoon, IIwl and IIs2 on better-drained areas beyond. Otakiri district, N68/187244 looking E.

IIwl -[1]

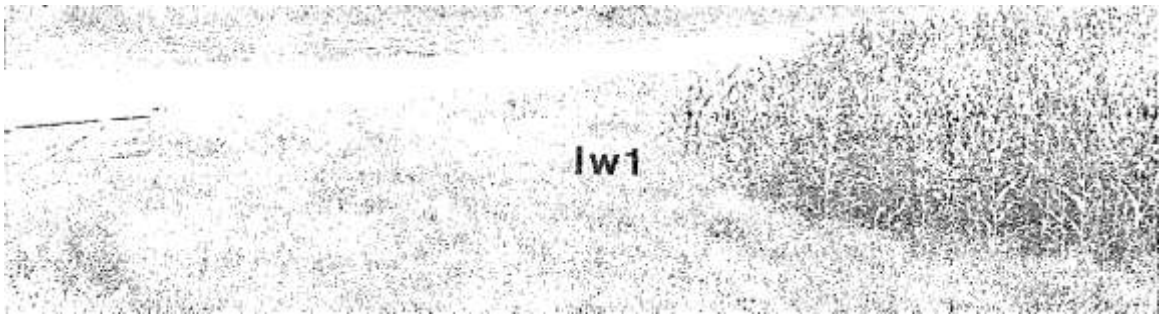


Fig. 16: LUC suite 3: Taken from stopbank beside Rangitaiki River, with Iwl (in foreground) sloping gently down to IIwl. Land use is maize cropping and intensive grazing use, but considerable intensification possible. Rewatu Rd, Whakatane district, N69/415228 looking SW.

' 7: 1.1 C suite 3: IIs2 on well-drained tephric alluvium with a thin mantle of Tarawera ash. Awakeri district, N68/305214 looking SW.

18: LUC suite 3: IIIwl on volcanic alluvium derived dominantly from Taupo Pumice in the northern Reporoa Basin. IVe7 (LUC subsuite 7d) and VIel7 (LUC subsuite 7b) on north--western edge of Kaingaroa Plateau, in background. Reporoa district, N85/840730 looking NNE.

> T

Fig. 19: LUC suite 3: IVwl within stopbanks of Whakatane River. Soils are fertile but area is severely limited by risk of flooding. Arawa Rd, Whakatane, N69/415236 looking NW.

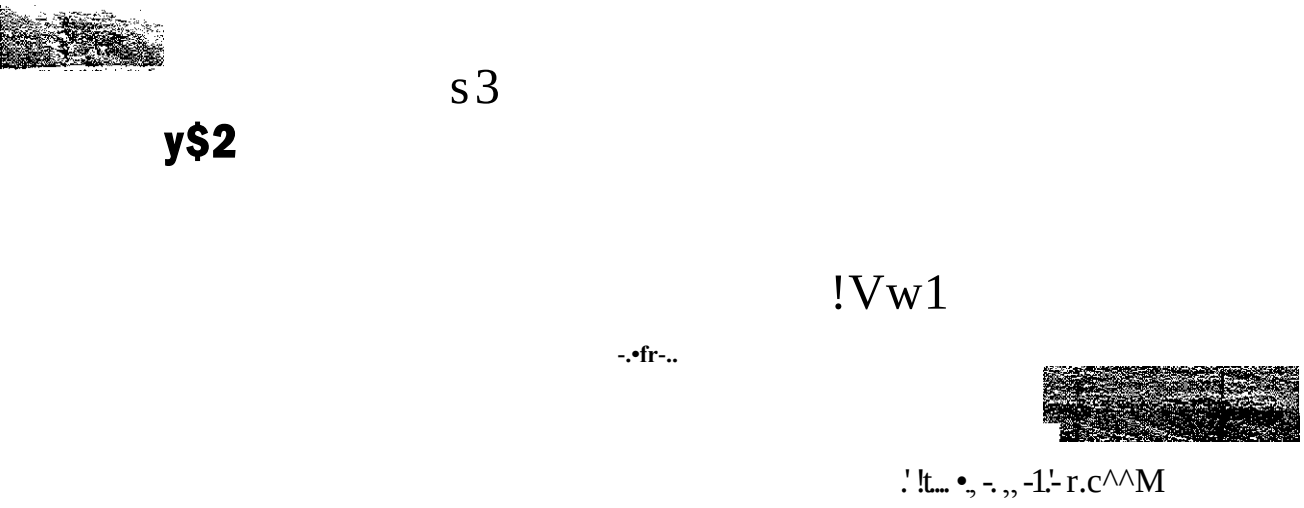


Fig. 20: LUC suite 3: IVwl and IVs3 on lower terrace of Whakatane River. IVwl (foreground) is subject to flooding. IVs3 (beyond stopbank) has soils limitation rather than flooding risk. IIs2 on higher terrace has intensive maize growing on fertile recent soils. North of Taneatua, N78/439170 looking E.

Fig. 21: LUC suite 3: IIIcl on volcanic alluvium in the Reporoa Basin. Moderately well-drained and fine-textured soils. Northern Paeroa Ranges (LUC subsuites 7c, 7e) in background. Wharepapa Rd, Reporoa district, N85/809702 looking NW.

ISSsS

Fig. 22: LUC suite 3: IIIs3 and IVs3 in the Galatea Basin on recent gravel and alluvial surface. IIIs3 on flat surface (foreground), IVs3 on sloping gravelly fan (middle of photo). A small stream which is the source of the alluvium emerges from the Ikawhenua Range (VllelO and VIIIe3, LUC subsuite 8a). Troutbeck Rd, Murupara district, N86/216670 looking SE.

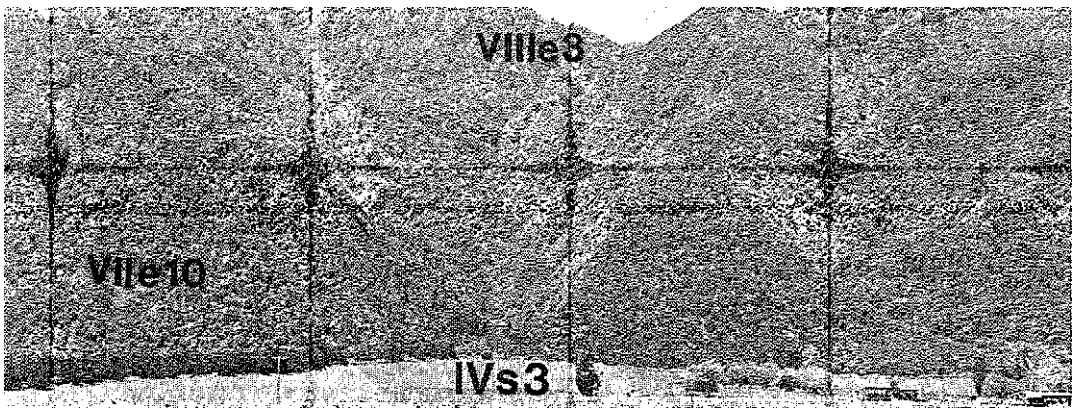


Fig. 23: LUC suite 3: VIwl on saline soils in estuarine conditions. IVel (LUC suite 1) on terrace behind. Wairoa River Railway Bridge, Tauranga district, N58/573590 looking SE.

ilililli

Fig. 24: LUC suite 3: VIIIwl in swamp enclosed between sand dunes. Vlllel **(LUC suite 2) on sand dunes behind. Matata district, N68/220334 looking NE.**

LUC SUITE 4: KAHAROA ASH

The characteristic of this LUC suite is the presence of Kaharoa Ash as a soil parent material. Kaharoa Ash is a loose white pumice ash sometimes including lapilli, dating from approximately 930 + 70 yr BP (Healy ***et al.*** 1964a)*. It gives rise to coarsely-textured and relatively low fertility soils that are prone to drought. The effects on these soils of a varied physiography and a very mild climate with slight summer moisture deficits, have given rise to a distinctive suite of LUC units.

Because of the recent age and porous nature of Kaharoa Ash, it influences soil properties even when present only as a shallow mantle. The LUC suite has therefore generally been mapped where Kaharoa Ash has a depth of more than approximately 8 cm (cf. LUC suite 7 on Taupo Pumice). It occurs to this depth or greater over almost the whole width of northern Bay of Plenty, from Tauranga to the Ohiwa Harbour, and as far south-east as the Murupara district (Fig. 25). The LUC suite is not, however, mapped over the whole of this area, because Kaharoa Ash in the central Bay of Plenty is overlain by recent tephras and tephric alluvium (LUC suites 6 and 3). The area included in the LUC suite is 209,800 ha, 11.8% of the total area of the region.

The LUC suite is divided into three subsuites. Two are distinguished by the depth of Kaharoa Ash: subsuite 4a is mapped where Kaharoa Ash is less than 30 cm deep, giving rise to composite yellow-brown pumice soils on yellow-brown loams, while subsuite 4b is mapped where Kaharoa Ash is more than 30 cm deep, giving rise to yellow-brown pumice soils. The third subsuite has a variable thickness of Kaharoa Ash but is distinguished from the other two subsuites by a distinctive mass movement erosion pattern.

Although the three subsuites are described separately, they form a continuum and overlap in many cases. In particular, although the boundary between the 'shallow' and 'deep' Kaharoa subsuites as shown in Fig. 25 roughly coincides with the 30 cm isopach of Kaharoa Ash, on LUC class I-IV land where Kaharoa Ash was 15-30 cm thick, the 'deep' Kaharoa subsuite was also mapped. The intention and effect of this was to restrict the arable 'shallow' Kaharoa subsuite to a narrower zone close to the coast, which contained the more suitable land for sub-tropical fruit growing.

LUC SUBSUITE 4a: SHALLOW KAHAROA ASH

General

This subsuite occurs where Kaharoa Ash has a depth of 8-30 cm thick, over deep 'Mo' ashes. Soil profile development has taken place in both types of tephra and the resulting soil, having properties from both, is called a composite yellow-brown pumice soil on yellow-brown loam (Rijkse 1974). The properties of these soils are reflected in land use capability; compared to LUC units on yellow-brown loams (LUC suite 1), LUC units in this subsuite are less versatile because of the coarseness and poor moisture-holding capacity of their upper soil horizons derived from Kaharoa Ash. This adversely affects pastoral performance, increases the potential for surface erosion, and may hinder crop establishment. However, if plant roots are able to reach more weathered ashes below the Kaharoa Ash the above factors become less significant. Therefore, because of a generally very favourable climate and good physical soil properties, much of this subsuite is highly suitable for forestry, orcharding and other deep-rooting crops. This is reflected in the extensive diversification that has taken place over much of the LUC suite, in which is located the centre of the New Zealand kiwifruit industry and one of the most important citrus-growing areas.

The largest areas of the subsuite are on the northern extension of the Mamaku Plateau running towards the Bay of Plenty coastline, and the northern edge of the Kaharoa Plateau (Fig. 25). It also occurs to the north-west of Lake Rotorua, on the north-east Kaingaroa Plateau, and in small areas to the east within LUC subsuite 4c. It does not generally occur

***In recent years, considerably younger ages have been suggested for Kaharoa Ash (e.g., McGlone 1983), but not yet confirmed.**

to the east of LUC subsuite 4b on deep Kaharoa Ash because those areas, on the flanks of the Ikawhenua Range, are very steep and the steepland soils mapped there do not have significant depths of Kaharoa Ash. Two LUC units in the subsuite (Vllel, VIIe2) have been much more widely mapped, throughout LUC subsuites 4a and 4b as well as to the south of LUC suite 4 (Fig. 25). This was because there were no additional LUC units created for areas where deeper Kaharoa Ash or shallow Taupo Pumice occurred on steep hill country (see p. 65).

The area of the subsuite is 85,550 ha, 41% of the Kaharoa LUC suite and 4.8% of the total area of the region. There are seven LUC units: IIsl, IIIe2, IVe2, VIe3, VIe4, Vllel, and VIIe2. They are distinguished according to slope, and in the non-arable LUC units also according to underlying rock types. Within the subsuite, areas of IIIwl (LUC suite 3) and VIIIe3 (LUC subsuite 8a) are mapped, as well as LUC units from the other Kaharoa subsuites. The boundaries of the subsuite largely occur along gradients of depth of soil parent materials, and therefore there is a continuum between LUC units in this subsuite and those of surrounding LUC suites.

Climate

The climate of the northern Bay of Plenty portion is similar to that of LUC suite 1, i.e., mild and moist, and exposed to tropical storms from the north and north-east. The representative climate station for this part of the subsuite is Te Puke. Further inland towards the Mamaku Plateau the climate becomes colder in winter with a greater frequency of frosts between May and September. Climatic conditions in areas south of Rotorua are similar to those described for LUC subsuites 7a and 7b.

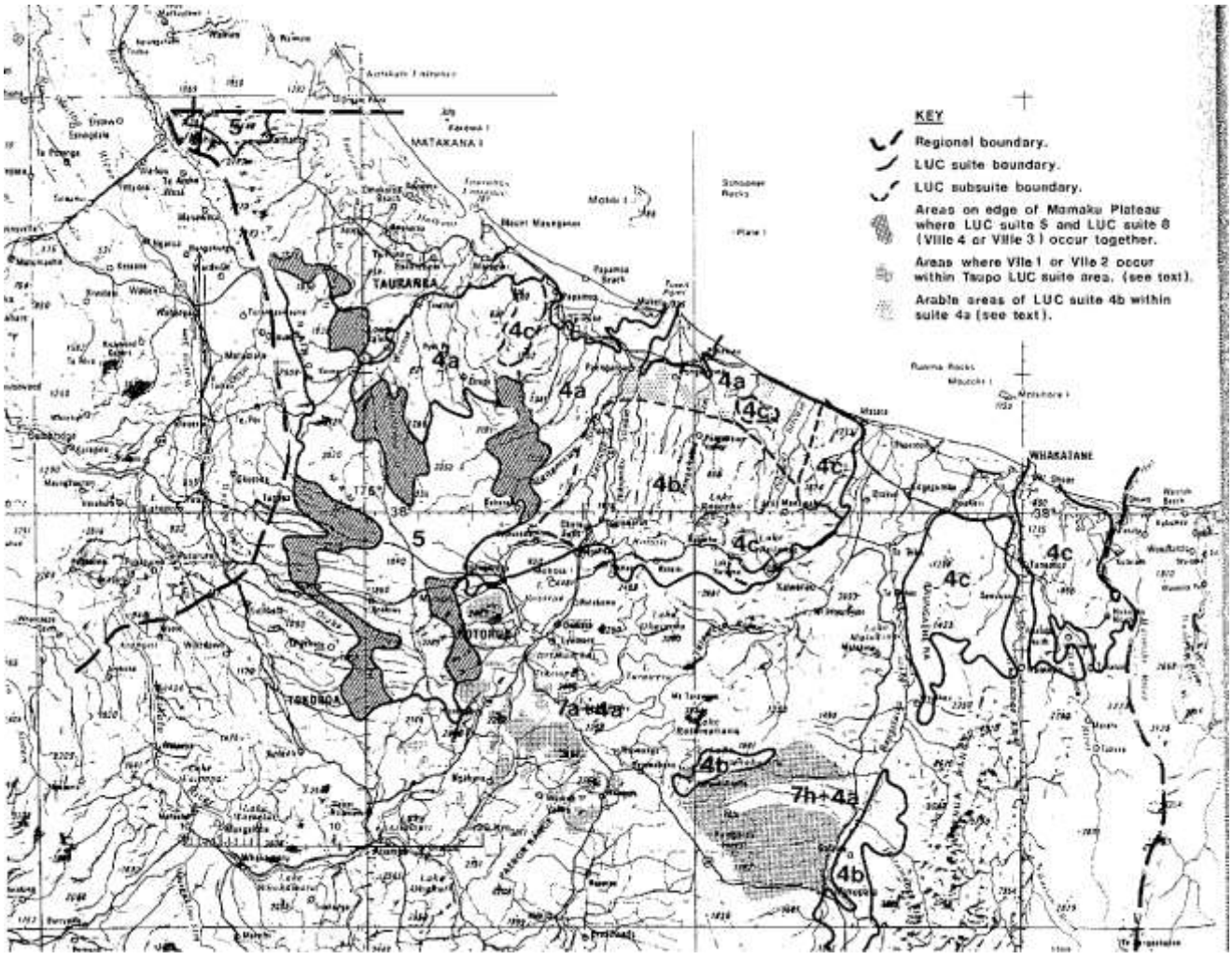


Fig. 25: Distribution of LUC suite 4 on Kaharoa Ash and LUC suite 5 on podzolised yellow-brown loams.

Physiography

The subsuite occurs in four physiographic situations:

a; On the northern extension of the Mamaku Plateau, on dissected ignimbrite country with deep, long north-south aligned gullies running through terraces of low relief.

b) On geologically complex hill country between the Tauranga and Maketu Basins bounded by two concealed faults.

c) On the northern Kaharoa Plateau, on terraces of fluviatile deposits or breccia, dissected by gullies. In these situations complexes of LUC subclasses Vie or Vile and Ille are mapped.

d) In the north-western part of the Rotorua Caldera, on lacustrine deposits of alluvial terraces, valley fills and fans associated with fluctuating lake levels since the eruption of Rotoiti Breccia **(c.** 42,000 years B.P.) (Kennedy ***et al.*** 1978).

The elevation rises from sea level at the Tauranga Harbour to approximately 350 m a.s.l. bounding the Mamaku Plateau. Overall, 40% of the subsuite is predominantly steep and 22% predominantly moderately steep (including those parts of Vllel and VIIe2 occurring outside the main area of the LUC subsuite), 33% is gently undulating to rolling, and only 4% is flat. Owing to the dissected nature of land in this subsuite, slopes are generally fairly short.

Rock Type and Soil Parent Material

Deep 'Mo' tephras mantle the whole of the subsuite area and were normally the uppermost rock type mapped. Various lapilli beds associated with the Mangaone Lapilli Formation are present throughout but were only recorded over 15% of the subsuite. Areas where they are especially significant have been separated into LUC subsuite 4c. Kaharoa Ash is normally not deep enough to be recorded in the rock type inventory except over about 12% of the area, almost all of this occurring where Vllel and VIIe2 was mapped in areas of deeper Kaharoa ashes (LUC subsuite 4b).

Over about 50% of the subsuite, the underlying rock type is Mamaku or Rangitaiki Ignimbrite, and over the other 50% it is various less consolidated rock types such as Rotoiti Breccia or fluviatile terrace deposits. Between the Tauranga and Maketu Basins a structurally complex mixture of ignimbrite, breccias, tuffs and interbedded siltstones and sandstones forms the underlying lithology.

Soils

65% of the subsuite was mapped using soils from the General Survey, and the remainder was mapped using soils from the Whakatane, Rotorua, Kaingaroa and Waiotapu Surveys. Because of the variable thickness of Kaharoa Ash within the subsuite, and the variable nature of Vllel and VIIe2 (see p. 69), the soil pattern is rather complicated. However, composite yellow-brown pumice soils on yellow-brown loams were recorded on 53% of the area, and related steepland soils on 30%. The latter group includes soils where Taupo Pumice is more significant than Kaharoa Ash; overall these soils occurred on about 15% of the total area.

Other soil groups include yellow-brown pumice soils and yellow-brown loams*. Yellow-brown pumice soils occurred either close to the boundary between LUC subsuites 4a and 4b, or in areas of thicker Kaharoa Ash as hill soils on less steep portions of Vllel and VIIe2. Small areas of composite recent soils on yellow-brown pumice soils were also recorded around the northern Rotorua Lakes on areas affected by thin Rotomahana Mud or Tarawera ash.

Yellow-brown loams were recorded to the west of Lake Rotorua on a small area adjacent to LUC subsuite 7a (this area was included in LUC subsuite 4a rather than in LUC suite

***The recent Te Puke soil survey has classified soils on the terraces between Tauranga and Te Puke as yellow-brown loams rather than as composite yellow-brown pumice soils on yellow-brown loams as shown in the General**
Survey. It has also mapped the boundary between composite yellow-brown pumice soils on yellow-brown loams (Paengaroa and Oropi series) and yellow-brown pumice soils (Ohinepanea series) running south from approximately
Pongakawa. This is about 1.5-2 km east of the boundary shown in the General Survey, with which the boundary between LUC subsuites 4a and 4b corresponds. This will have the effect, in future remapping, of reducing the

1 from which it differed significantly in climate—see p. 39) and also south of Rotorua on less steep portions of Vllel and VIIe2 where both Kaharoa Ash and Taupo Pumice were very thin. In summary, it can be seen that the pattern of soils shows a continuum between areas where Kaharoa Ash is insignificant and areas of deep Kaharoa Ash.

Erosion

Slight erosion was recorded on map units covering 40% of the subsuite and moderate erosion on map units covering 7%. Little erosion occurs on arable land while on non-arable land the main types of erosion are soil slip and sheet. They often occur together but sheet erosion tends to have a greater severity both in present and potential erosion. This reflects the low water-holding capacity of the Kaharoa Ash. Earth slip, gully and streambank are minor erosion types, the last two often occurring on colluvial ashes in valley heads or on valley floors. Potential erosion severity is assessed as severe in steepland areas and slight to moderate elsewhere, while erosion associations identified are T on the terraces and P in the hill country.

Land Use and Land Management

The present land use pattern shows a conspicuous contrast between three distinct areas: firstly a belt of highly developed land close to sea level, where the climate is most favourable, on which the land use is dominated by intensive dairying, stock fattening and orcharding; secondly the 'back country' of the northern Mamaku and Kaharoa Plateaux, where there is more extensive sheep, cattle and deer farming and a much higher proportion of undeveloped land; and thirdly the steeplands of the north-eastern Kaingaroa Plateau and southern Rotorua district, which is dominated by exotic forestry. On the Kaharoa Plateau, land use closely follows the distribution of soils, its pattern gradually changing from that found in LUC suite 1 (yellow-brown loams) to the north, to that found on LUC subsuite 4b (yellow- brown pumice soils) to the south-east.

Overall, pastoral land uses are dominant, with sheep, cattle and deer raising and dairying together occupying about 60% of the total area. Orchards, predominantly kiwifruit and citrus fruit, occupy about 5%, and exotic forestry about 10% of the area. The remainder is undeveloped, consisting principally of cutover podocarp-hardwood forest together with indigenous scrub, small indigenous forest remnants within pasture land, and mixtures of rough pasture and scrub. Gorse is the main exotic weed.

Land in this subsuite has the potential for considerable diversification and intensification. Potential stock carrying capacities as well as exotic forest growth potentials are generally moderately high to very high. Arable land near sea level has excellent horticultural potential for kiwifruit and other crops such as berry fruits and vegetables, although shelter and contour cultivation are essential soil conservation requirements and irrigation would be beneficial. (Many of the soils in this subsuite that are most suitable for horticulture are in fact yellow-brown loams (p. 65) rather than the Oropi and Paengaroa series shown in Table 14. Oropi soils occur in the higher and colder parts of the subsuite, while some Paengaroa soils are particularly susceptible to drying out.) It seems certain that there will be a continuing trend towards horticulture in the coastal area and probably also in the Rotorua district. This is emphasised by NWASCO (1982), which recommended a three-fold increase in the area of sub-tropical fruits at the expense of dairying and sheep and cattle rearing. However, land recontouring for horticulture (Fig. 29) is subject to the same constraints as for LUC suite 1 (p. 39).

Non-arable land under pastoral use, especially in drier areas, is subject to limitations of erosion, nutrient depletion, and weed and insect pest problems. (Pasture establishment on arable land after cropping is subject to the same limitations.) Soil conservation measures should aim to minimise bare ground exposure, especially by control of cattle numbers and open planting of potential slip faces. On extensively developed or undeveloped land, a shift away from sheep and cattle breeding to exotic forestry and deer farming can be expected. On steepland areas (Vllel and VIIe2), pastoral use requires great care in management to minimise bare ground exposure, and forestry use requires adherence to the "Forestry

Operations" guidelines (NWASCO 1976). It would also be desirable to retain some undeveloped gullies for water and soil and habitat conservation. A considerable portion of the land fringing the northern Rotorua Lakes, as well as other smaller areas, is in scenic reserves.

LLC Units on Shallow Kaharoa Ash (Table 14)

LLC unit **IIsl (9,500 ha)—**Figures 26, 27

This LUC unit occurs on gently undulating terraces in the coastal Bay of Plenty between Tauranga and Otamarakau, especially on the terraces south and east of Te Puke. There is little erosion risk and the main limitation to use arises from the drought-prone topsoil derived from Kaharoa Ash. However, because of favourable climate and soil physical properties, Itsl is particularly suited to the growing of subtropical fruits, especially kiwifruit which was pioneered as a horticultural industry on IIsl terraces around Te Puke. Citrus orchards also occupy a significant area. Of all LUC units in the Bay of Plenty, IIsl has witnessed the largest wing from the traditional land use of dairying to horticulture, which has possibly already become the dominant land use. This trend will probably continue. Out-of-season frosts will limit production in some years, and protection from wind is very important. Iisl also has a very high potential stock carrying capacity and exotic forestry growth potential.

LUC unit IIIe2 (10,200 ha)—Figures 26, 27, 28

This LUC unit occurs on undulating to gently rolling slopes with shallow Kaharoa Ash, which have a potential for slight to moderate erosion under cultivation. It has a similar distribution to IIsl, but is also found in the north-west of the Rotorua Basin. On the terrace country of the northern Kaharoa Plateau it is frequently intersected by gullies with which, at the NZLRI mapping scale, it is sometimes mapped in complexes. It is occasionally mapped on alluvial or colluvial ashes in the bottom of these gullies where they are wide enough. In general IIIe2 is very similar to IIsl except for its slightly steeper slopes and resulting higher erosion potential. Erosion may be minimised by contour cultivation and provision of shelter.

The main land uses on IIIe2 are dairying and orcharding with a small amount of sheep and cattle grazing and undeveloped land. It is likely that dairying and orcharding will become the only significant land uses except for small areas adjacent to the Mamaku Plateau. The area near Lake Rotorua has a slightly lower arable potential because of winter frosts, although it is very suitable for some horticultural crops, especially pip fruit. Although the versatility of IIIe2 is slightly less than that of IIsl, its potential for many horticultural crops such as kiwifruit would be similar. It also has a generally very high exotic forestry potential.

LUC unit IVe2 (8,650 ha)—Figures 30, 31

This LUC unit occurs on rolling to strongly rolling slopes with shallow Kaharoa Ash, which have a potential for moderate to severe erosion under cultivation. It occurs throughout the subsuite, especially between Tauranga and the Mamaku Plateau. Scattered areas also occur in the north-west Rotorua Basin, and in the Waimana district within LUC subsuite 4c (on Whakatane soils) on easy slopes where the subsurface lithology does not influence the erosion pattern (see p. 82).

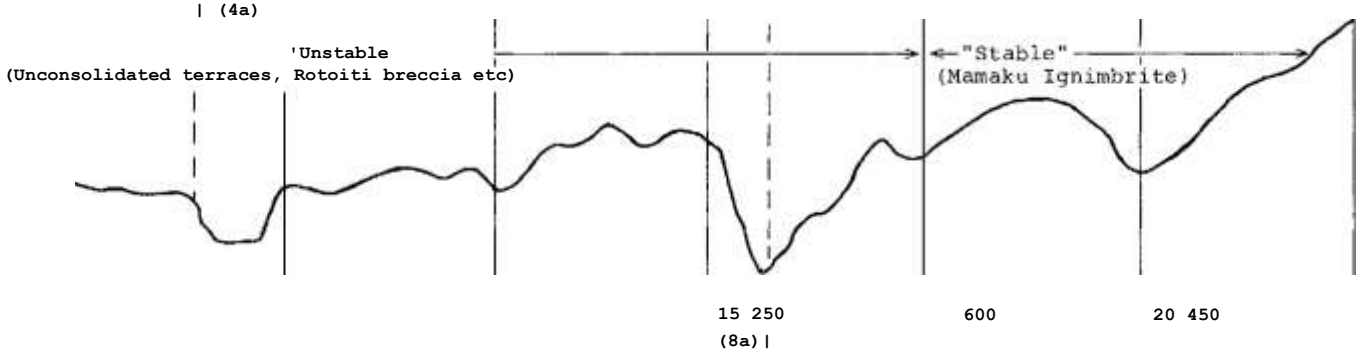
The inventory factors recorded on IVe2 are similar to those of IIIe2 except for steeper slopes which significantly decrease its versatility and land use potential. There is a potential for severe rill and sheet erosion under arable use, although with appropriate soil conservation techniques easier slopes are suitable for deep-rooting crops. Soils occurring near the Mamaku Plateau are moderately leached (Oturoa series). Although dairying is the dominant land use, sheep and cattle rearing is more important than on IIsl or IIIe2. Undeveloped land comprises about 10% of the area. Both dairying and orcharding will continue to be important land uses, with sheep and cattle grazing more important in inland districts. The exotic forestry potential is also generally very high.

LUC unit VIe3 (8,600 ha)—Figures 30, 31

This LUC unit consists of moderately steep to steep stable hill country with shallow Kaharoa Ash over 'Mo' ashes. It occurs mainly on the northern Mamaku Plateau and in

TABLE 14: LUC units on shallow Kaharoa Ash.

LUC UNIT	IIs 1	IIIe2	IVe2	VIe4	VIIe2	VIe3	VIIe1
RELATED LUC UNIT (LUC Suite)		I IIIw1 I VIIe2 (4a)			VIIIe3		
PHYSIOGRAPHY							
AREA (ha)	9 500	0	1Sh(2-3Sh,R,W)	& deer Undeveloped	Oropi Oturoa	2- 3Sh; 2sSl	
SLOPES	B A +	0	Dairying Sheep & cattle Orcharding Undeveloped	F F + E	66	Undeveloped Exotic forestry Sheep,cattle & deer	
SOILS	Oropi Paengaroa	0(2R; 1Sh,W)	12 900	Pukemaku Otanewainuku Pohaturoa	ISh,sSl 2Sh,sSl		
% MAP UNITS CONTAINING EROSION	0	Dairying Orcharding Sheep & cattle Undeveloped	E E + F E + D	82	Sheep,cattle & deer Undeveloped Exotic forestry		
PRESENT EROSION	0	8 650	Oropi Whakatane Paengaroa	1-2Sh,sSl; 1G 3Sh,sSl,G	F F + G		
POTENTIAL EROSION	0 (1W)	C C + D C/D	76	Undeveloped Sheep,cattle & deer Exotic forestry	Otanewainuku Oropi Tauhara Haroharo		
PRESENT LAND USE	Dairying Orcharding 10 200 B + C	Oropi Paengaroa Whakatane	1-2Sh; lsSl,G 2Sh,sSl,G	E E + F	59 1- 2Sh; lsSl		
	Oropi Paengaroa Oturoa	14 ISh	Sheep,cattle				



STOCK CARRYING CAPACITY (s.u./ha)	16, 21, 26
SITE INDEX (m)	35-41
	15, 19, 21
	34-40
	14, 18, 20
	33-41
	14, 17, 19
	35-40
	14, 16, IS
	33-39
	14, 17, 19
	35-40
	12, 15, 15
	27-40

the north-west Rotorua Basin. The underlying rock type is almost all Mamaku Ignimbrite. As with VIe4, there is a deep tephra cover often including lapilli, and a variable thickness of Kaharoa Ash of up to 30 cm. Compared with IVe2 there is a greatly increased incidence of sheet and soil slip erosion, especially under pasture, although their mapped severity is slight.

VIe3 is predominantly used for sheep and cattle grazing, both for breeding and fattening. About 15% of the area, mainly higher country towards the Mamaku Plateau, has an indigenous forest or scrub cover. Exotic forest is at present a very minor land use but because VIe3 has a very high site index as well as a moderately high stock carrying capacity, a trend towards mixed exotic forestry and pastoral use is likely. Almost half of the present pastoral area has a cover of grassland/scrub mixtures, so considerable scope exists for intensification of pastoral use.

LUC unit **VIe4 (12,900** ha)—Figures 30, 33

This LUC unit consists of strongly rolling to steep hills with a thin mantle of Kaharoa Ash over 'Mo' ashes on unconsolidated rock types. It occurs mainly on the northern Kaharoa Plateau in a strip about 6 km wide running to the sea between Pongakawa and Hereperu Stream. Here it is mapped on hill country and dissected terrace country on Rotoiti Breccia (frequently recorded with IIIe2 on the terraces). It also occurs in the Ohauiti-Mt Misery district and in the north-west Rotorua Basin. VIe4 generally occurs on slightly easier but more broken slopes than VIe3. It has a slightly different erosion pattern to that on VIe3, with erosion recorded on map units covering nearly 80% of its area, occasionally of moderate severity. Although the balance between soil slip and sheet erosion is comparable to that on VIe3, gully erosion is also significant.

VIe4 has a predominantly pastoral present land use although less intensive than on VIe3, with about 50% of the area undeveloped or little developed. There are significant remnants of hardwood forest within pastoral land. Vle4 has similar potential stock carrying capacity and exotic forest growth potential to that of Vle3, and a similar trend to mixed pastoral and exotic forest use can be envisaged, although a greater percentage of gullies and broken country will be more suited to exotic forestry. Soil conservation measures should aim for gully control as well as minimising the incidence of bare ground.

LU: unit **Vllel (20,450** ha)—Figures 31, 62, 96

This LUC unit consists of steep hill country with a shallow mantle of Kaharoa Ash (or sometimes Taupo Pumice) over 'Mo' ashes on stable rock types. It occurs throughout LUC subsuites 4a and 4b as well as within the Taupo Pumice LUC suite (Fig. 25). Its largest area is the steep hills and gullies of the Kaharoa and northern Mamaku Plateaux. It also occurs on the north-east corner of the Kaingaroa Plateau (together with LUC subsuite 7h) and on rhyolitic extrusions in the Rotorua and northern Ngakuru districts.

The underlying rock type is usually ignimbrite but includes Haparangi Rhyolite in the Rotorua district. 'Kt' ashes are recorded as a surficial rock type over 19% of the LUC unit. Because it was mapped in areas of variable depth of ash, including areas where Taupo Pumice rather than Kaharoa Ash is significant (see p. 64), the soils of Vllel are rather variable. The main soils found in the various areas of the LUC unit are:

a) ***Kaharoa and Mamaku Plateaux:*** Composite yellow-brown pumice soils on yellow-brown loams and related steepland soils, yellow-brown pumice soils and related steepland soils derived from Kaharoa Ash (Oropi and Otanewainuku series). Some of these soils are podzolised.
b) ***Kaingaroa Plateau:*** Hill soils and steepland soils related to yellow-brown pumice soils, where Kaharoa Ash is underlain by Taupo Pumice (Otanewainuku and Pekepeke series). Includes areas overlain by Tarawera ash (Haroharo series).
c) ***Rotorua district:*** Steepland soils derived principally from Taupo Pumice although with Kaharoa Ash present (Pohaturoa, Arahiwi, Tauhara series).

Vllel is generally fairly stable, with only slight present erosion. However, there is a severe sheet erosion potential on the steeper slopes. Its natural soil fertility is low and weed reversion a continuing problem, hence it has not been extensively developed for grazing in spite of a generally favourable climate. Only 22% of the area has a dominantly pasture cover, and there are large areas of cutover hardwood forest, indigenous scrub and mixtures of forest, scrub and rough pasture. The major single land use is exotic forestry; this covers about 38% of the area, concentrated on the Kaingaroa Plateau. Because of the potential erosion problems and the differences in potential between pastoral and forestry use, NWASCO (1982) has recommended exotic forestry over all of Vllel. However, the scattered nature of the LUC unit, together with access difficulties, will probably preclude some areas from either forestry or agricultural use.

LUC unit VIIe2 (15,250 ha)—Figures 28, 32

This LUC unit consists of steep and moderately steep hill country with a shallow mantle of Kaharoa Ash (or Taupo Pumice) over 'Mo' ashes on unconsolidated rock types. It is scattered throughout the Bay of Plenty but is concentrated on the Kaharoa Plateau, around the northern Rotorua Lakes on Rotoiti Breccia and lacustrine terrace deposits, and south of Rotorua on various unconsolidated lithologies, e.g., Huka Formation and Earthquake Flat Breccia. It does not occur on the Kaingaroa Plateau. On the Kaharoa Plateau it often occurs on valley sides, associated with LUC subclass Hie or IIIw on the valley floors.

Because VIIe2 was extended outside the area of influence of Kaharoa Ash in the same way as Vllel, it has similarly variable soils. The main differences are that there is a greater influence from Tarawera ash (Pukemaku Series) and that Pekepeke soils are not mapped. It has a similar relationship to Vllel as does VIe4 to VIe3 in that it is slightly more broken and less steep (23% of its area has predominantly hill soils recorded), and has more erosion recorded at both slight and moderate severities. VIIe2 is subject to streambank erosion, locally severe, occurring where gully bottoms and river flats have been included in the LUC unit at the scale of mapping. It has a severe potential for gully and streambank erosion in these situations.

VIIe2 is slightly more developed for pastoral use than is Vllel, and has only about 20% developed for exotic forest. As with Vllel a trend to exotic forest (high to very high growth potential) is recommended in NWASCO (1982), but this is likely to be incomplete because of a moderately high stock carrying potential, access problems (as for Vllel), and the existence of substantial areas of scenic reserves around the northern Rotorua lakes.

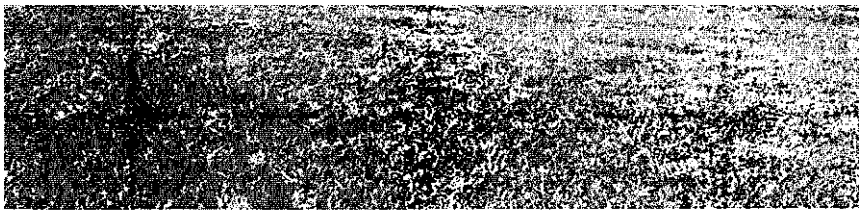
.1,

9MHB

Fig. .'-..': LUC **subsuite 4a: General view over Otamarakau terraces. Front flat terrace tops are IIsl. Terraces behind are IIIe2, mapped in complex with VIe4 in gullies. (Terrace scarp in foreground would be mapped as VIIe2 in detailed mapping.) McDougall's Quarry Rd, Ohinepanea district, N68/004388 looking** NW.

IIwl.

till



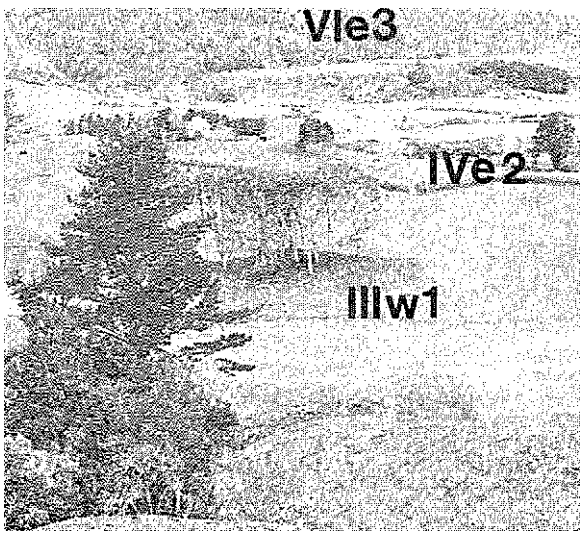
27: LUC **subsuite 4a: IIsl (midfield) and IIIe2 (foreground). Intensive dairying and subdivision for kiwifruit. Valley bottom in right midfield is mapped as IIwl** (LUC **suite 3). Paengaroa district, N67/862457 looking S.**

Fig. 28: **LUC subsuite 4a: Typical valley system in the southern Tauranga Basin. Sloping terrace in valley is IIIe2, as are terraces on top of valley sides, which are VIIe2. IIIwl (LUC suite 3) in lower-lying parts of valley. Joyces Rd, south of Tauranga, N58/605507 looking SE.**

Fig. 29: **LUC subsuite** 4a: **Recontouring of land for horticulture. Natural contour is strongly rolling but soil has been redistributed to give more gently rolling surfaces. Papamoa district, N58/730550 looking SW.**

IVe2

JC subsuite 4a: **IVe2 in foreground. VIe4 in left background on Huka sediments and** VIe3 **in right background on rhyolite. Ohauiti district, N67/652474 looking S.**



: LUC subsuite 4a: VIe3 (foreground and right background) and Vllel (left background) on stable rhyolitic country. IVe2 on rolling land in basin and IIIwl (LUC suite 3) on lower-lying land. Ohauiti Rd, Oropi district, N67/658437 looking SE.

LUC SUBSUITE 4b: DEEP KAHAROA ASH

General

This subsuite occurs in areas where Kaharoa Ash is greater than 30 cm deep, giving rise to yellow-brown pumice and related soils. The effect of the greater depth of Kaharoa Ash (compared with LUC subsuite 4a) on land use capability is that the soils are coarser, have poorer water-holding capacity and are more susceptible to surface erosion, and therefore arable and pastoral potential is generally lower. However, forestry potential is not significantly affected because tree roots are able to penetrate to more weathered tephras beneath the Kaharoa Ash.

The distribution of the subsuite is shown on Fig. 25. Its main area is on the Kaharoa Plateau. Other areas occur around Lake Rerewhakaaitu, along the northern fringes of the Kaingaroa Plateau, over much of the Galatea Basin and on hills to the south-east of Murupara. Small areas occur on easier slopes within the hill country between Te Mahoe and Taneatua. On arable land on the northern Kaharoa Plateau it also extends into LUC subsuite 4a as shown on Fig. 25.

The area of the subsuite is 65,000 ha, 31% of the Kaharoa LUC suite and 3.6% of the total area of the region. There are six LUC units: IIIs4, IIIe5, IVe5, VIe8, VIel 5 and VIIe9. They are distinguished from each other largely on slope, with the non-arable LUC units also distinguished by their underlying rock type. VIIe9 is rather restricted in its occurrence (see p. 79) and most steeplands are included in LUC subsuite 4a (Vllel or VIIe2) because they have thinner Kaharoa Ash (see p. 64).

At its edges this subsuite grades into a number of other LUC subsuites, i.e., subsuites 4a and 4c, subsuite 6a where Tarawera ash becomes significant south of the Kaharoa Plateau, subsuite 7c where Taupo Pumice becomes significant in the south-east, and subsuite 7h at the northern edge of the Kaingaroa Plateau.

Climate

The Kaharoa Plateau has a climate intermediate between a maritime coastal climate (as in LUC subsuite 4a) and the inland Bay of Plenty climate around Rotorua (as in LUC subsuite 6b). It is characterised by higher rainfall and cooler winter temperatures than at the coast. The representative climate station for this area is Rotoehu Forest. Areas of the subsuite in the Galatea and Rerewhakaaitu districts differ in having a lower annual rainfall, especially in summer, and a generally lower temperature regime. In the surrounding hill country, rainfall is slightly higher. Winters are foggy. Representative climate stations for these areas are Murupara and Waiotapu Forest.

Physiography

This subsuite occurs in the following physiographic settings:

a) On the Kaharoa Plateau, which slopes gently on a surface of Rotoiti Breccia from 300 m a.s.l. at Lake Rotoma down to 100 m a.s.l. The plateau surface varies from flat to hilly and is frequently dissected; more than 50% is dominantly moderately steep, while about 25% is undulating to rolling.

b) Around the northern Rotorua Lakes where the Kaharoa Plateau adjoins the Okataina Volcanic Centre. This area consists of short steep slopes rising from the lakes, broken by recent alluvial terrace deposits.

c) In the Galatea Basin, a fault-angled depression lying at 170-225 m a.s.l. It has been intermittently infilled with detritus from the surrounding ranges, forming older fans and terraces mantled by a succession of tephras (this subsuite), and younger floodplains of presently accumulating alluvium (LUC suite 3). The physiography of the basin has been discussed in detail by Pain & Pullar (1968).

d) To the south-east of the Galatea Basin, on hills which are fault-bounded outliers of the Ikawhenua Range.

e) Areas between Te Mahoe and Taneatua on the Raungaehe Range, a low-lying northern outlier of the Ikawhenua Range, partly overlain by ignimbrite from the west.

f) On low-lying and relatively flat ignimbrite surfaces around Lake Rerewhakaaitu and the northern Kaingaroa Plateau.

Rock Type and Soil Parent Material

The whole subsuite is mantled by Kaharoa Ash up to 1 m thick, which was recorded as the topmost rock type over 75% of the area. Tarawera ash also mantles most of the subsuite to a depth of approx 8-15 cm but was not recorded as a rock type. The subsuite has also been mantled with great thicknesses of older tephras, especially Rotoehu Ash which was associated with the Rotoiti Breccia (Nairn 1972; Walker 1979). Total thickness of tephra cover on the Kaharoa Plateau is generally in excess of 40 m and over 100 m in places. Tephra thickness over the older parts of the Galatea Basin is 3-6 m. 'Mo' was recorded as the surficial rock type in arable areas where Kaharoa Ash was 15-30 cm thick (see p. 63), and on steeper slopes where Kaharoa Ash distribution was patchy. As in LUC subsuite 4a, Mangaone Lapilli Formation is significant throughout the northern portion, but was generally included within the 'Mo' ashes. However, those areas where it was recognised as being especially significant in the landscape were separately recorded within LUC subsuite 4c. Much colluvial and alluvial redistribution of tephra has occurred in gullies on the Kaharoa Plateau, and where this has been especially pronounced volcanic alluvium (Tp) has been recorded.

The basal rock type recorded over most of the subsuite was Rotoiti Breccia (recorded as Ft), a poorly compacted white pumice ignimbrite breccia, erupted in a great sheet from the Haroharo area approximately 42,000 years B.P. (Nairn 1972; Nairn & Kohn 1973). It overlies older and harder ignimbrites, which were occasionally recorded (as Vo) in the rock type inventory where they are significant underneath eroded Rotoiti Breccia. Vo was also recorded in areas in the Raungaehe Range and west of Te Whaiti. Greywacke is significant in small areas south of the Galatea Basin. In the Galatea Basin the underlying rock type is greywacke- and ignimbrite-derived gravels, which are mixed with finer sediments and mapped together as Us.

Soils

50% of the subsuite was mapped using soils from the General Survey. Smaller areas were mapped using soils from the Whakatane, Kaingaroa and Rotorua Surveys.

The largest grouping of soils was yellow-brown pumice soils and composite recent soils on yellow-brown pumice soils, recorded on the southern Kaharoa Plateau where Tarawera ash was between 8 and 15 cm thick (Matahina and Manawahe series). These two groups together cover about 75% of the subsuite, an area roughly corresponding to that where Kaharoa Ash was recorded in the rock type inventory. Some of the yellow-brown pumice soils recorded on and around the southern Galatea Basin have significant depths of Taupo Pumice underlying the Kaharoa Ash (Pekepeke series).

In the north-west of the subsuite where Kaharoa Ash has a thickness of 15-30 cm, arable areas with composite yellow-brown pumice soils on yellow-brown loams (Paengaroa and Oropi seris) were included in this subsuite (see p. 63). Some of these areas may be reclassified into subsuite 4a in future remapping (see p. 65, note). Some small areas north of Lake Rotorua whose soils were classified in the Rotorua Survey as composite yellow-brown pumice soils on yellow-brown loams were also included. Several of the soils mentioned above, occurring in areas with greater than 1500 mm annual rainfall, are weakly podzolised.

Most areas of steepland soils within the subsuite have thin or patchy Kaharoa Ash and were therefore included in LUC subsuite 4a (Vllel or VIIe2), except for small areas of steepland soils on land mapped as VIIe9.

Erosion

The erosion pattern is rather similar to that on LUC subsuite 4a, with sheet and soil slip being the most important erosion types. Perhaps surprisingly, considering the greater depth of Kaharoa Ash, there has not been a significantly greater amount of erosion recorded than in LUC subsuite 4a; it is claimed that on the northern Kaingaroa Plateau even thick Kaharoa ash is remarkably stable on slopes up to 35(Vucetich ***et al.*** 1960, p. 30). Also the inclusion

of the steeper slopes of Vllel and VIIe2 in LUC subsuite 4a tends to mask any difference.

Overall, slight erosion was recorded on map units covering 39% of the subsuite, moderate erosion on map units covering 9%, and severe erosion on map units covering 1%. Sheet is the most important erosion type, being recorded on map units covering 40% of the subsuite (83% of the area of map units on which erosion was recorded). Sheet erosion was approximately four times more prevalent on areas of dominantly pasture vegetation than on areas of other vegetation. Soil slip erosion was often recorded with sheet erosion, but not often as the only erosion type. Gully and streambank erosion is localised in colluvial stream bottom situations but is severe in places. In general much of the erosion occurs in the surficial tephras (including redeposited tephras), affecting underlying rocks significantly only in VIIe9. The dominant erosion association was classified as association P, with association T occurring in the Galatea Basin.

Land Use and Land Management

Sheep and cattle grazing occupies about 30% of the subsuite, dairying and exotic forest each about 20%, and the remainder is undeveloped. Undeveloped land mainly comprises indigenous scrub within pastoral land, or pockets of logged hard wood forest. A clear difference can be seen in both the present and the potential land use pattern between the Kaharoa Plateau and the Galatea-Rerewhakaaitu district.

On the Kaharoa Plateau, dairying is the predominant land use on the easier and lower-lying land, with dry stock farming (including deer) elsewhere. Exotic forestry is also important. Future development will reflect the relatively favourable climate with good seasonal growth rates, balanced against inherently infertile and drought-prone soils. Diversification is possible in the northern and western portions of the subsuite where kiwifruit and other orcharding and horticultural crops can be grown on flat to rolling arable land, although yields are lower than in other Bay of Plenty districts. Dairying and grazing also have a moderately high to high potential. Irrigation may be necessary to achieve production potentials. Higher on the plateau, and on the Raungaehe Range, an intensification of present grazing management (present average stocking levels are medium) is possible, particularly on easier land, through development of scrub-covered land, top-dressing, controlled grazing and other soil conservation measures discussed under the individual LUC units. In general, soil conservation measures for this subsuite are similar to those discussed in LUC subsuite 4a, but a greater intensity of conservation management is required. However, a continuing erosion potential under pastoral management, and a very high exotic forest growth potential for all LUC units, supports a trend to exotic forestry. NWASCO (1982) recommends exotic forestry on 50% of the total area of the subsuite. However, there would be some access problems (as with LUC subsuite 4a), and pressure for preservation of remaining remnants of indigenous forests (especially around the northern Rotorua lakes).

In the Galatea Basin and Rerewhakaaitu district, dairy farming is the dominant land use, with some subsidiary sheep and cattle farming, and with some exotic forestry both in woodlots and along the edges of the Kaingaroa Forest. Dairying use is dependent on winter fodder and lucerne cropping. These areas have a high potential stock carrying capacity; the present land use pattern can be envisaged to continue, possibly with some minor development of frost-tolerant cereal or horticultural crops.

LUC Units on Deep Kaharoa Ash (Table 15)

LUC unit **IIIs4 (10,600 ha)—**Figures 33, 35

This LUC unit occurs on flat to gently undulating plains and terraces mantled with deep Kaharoa Ash, which are subject to severe summer drought. It occurs in two distinct physiographic areas: most of it comprises the older detrital terraces of the Galatea Basin, while the remainder occurs on flat areas on the northern Kaharoa Plateau and north of Lakes Rotorua and Rotoiti. In the latter situation Kaharoa Ash overlies very thick older ashes, with slightly podzolised Oropi soils, but in the former, the terraces have largely been formed since the Rotoehu eruption and there is only 3-6 m of tephra overlying greywacke and ignimbrite detritus. The resulting soils (Galatea or Kopuriki series) are distinctly drought-

TABLE 15: LUC units on deep Kaharoa Ash.

LUC UNIT	IIIs4	IIIe5	IVe5	VIe8	VIe15	VIIe1 VIIe2 VIIo9 i
RELATED LUC UNIT (LUC Suite)	IIIs3 IVs3	Vile 2 (4a)				VIIe1 VIIe2
PHYSIOGRAPHY	(3) Flood-plain	Ash-covered detrital terraces in tectonic basin	-covered tructural races	Valley sides	y Rolling terraces	Stable hill country	Broken hill country and valleys	(4a) Steep hill country	Steep hills and gullies of eroded breccia
AREA (ha)	10 600	5 750	8 350	6 700	28 250	5 300
SLOPES	A B	B B + C	C C + D	E + F E D	E E + F E + D	F F + G
SOILS	Galatea Kopuriki Oropi	Paengaroa Manawahe	Manawahe Ohinepanea Paengaroa	Pekepeke Tarawera Oropi Ruakituri	Manawahe Rotoiti Paengaroa	Oropi Otanewainuku Rotoiti
% MAP UNITS CONTAINING EROSION	0	33	24	73	71	74
PRESENT EROSION	0	l-2Sb; ISh	lSh,Sb	l-2Sh; lsSl,G	l-2Sh; lsSl,G	1-3G; l-2Sh; lsSl
POTENTIAL EROSION	0(lW,Sb)	0(2Sh,W,Sb ,R)	lSh,R (2-3Sh,W,R; lSb)	2Sh,sSl; 1G	2Sh,G,sSl	3G,sSl; 2Sh,T
PRESENT LAND USE	Dairying Exotic forestry	Dairying Undeveloped	Dairying Sheep,cattle	Sheep,cattle, deer	Sheep,cattle deer	Exotic forestry Undeveloped

prone. Kopuriki soils occur further north than Galatea soils and are overlain by 2-8 cm Tarawera ash. The two series differ somewhat in subsoil properties and degree of leaching. However, the amount of flat land in the subsuite occurring with Kopuriki soils was not enough to warrant the creation of a separate LUC unit. In the Galatea Basin, IIIs4 does not differ greatly from IIIs3 (LUC suite 3) (see p. 56).

IIIs4 has a slight potential for wind erosion when cultivated, thus provision for shelter is the main recommended soil conservation measure. Dairying is well established as the main land use, especially in the Galatea Basin. The potential stock carrying capacity is high but may be slightly depressed on drought-prone soils in the Galatea Basin, where lucerne and winter fodder cropping are necessary to overcome depressed pasture production due to seasonal extremes of dryness and temperature. There is a very high exotic forestry potential, and some potential for horticulture.

LUC **unit IIIe5 (5,750 ha)—**Figures 32, 34, 96

This LUC unit occurs on gently undulating to rolling slopes mantled with deep Kaharoa Ash. It occurs on the Kaharoa Plateau, around the northern Rotorua lakes, and in small areas on the Raungaehe Range, south of the Galatea Basin, and south and east of Lake Rerewhakaaitu*. Between Otamarakau and Pikowai IIIe5 extends as far north as the Bay of Plenty coast.

In the south, IIIe5 is mantled with shallow Tarawera ash, giving rise to composite recent soils on yellow-brown pumice soils (Manawahe series). However, in coastal Bay of Plenty districts, IIIe5 has a shallower mantle of Kaharoa Ash (15-30 cm) and therefore a significant proportion of composite yellow-brown pumice soils on yellow-brown loams (Paengaroa series). In this coastal area it also occurs in valley bottoms on colluvial ash where it may include LUC class VHIe gullies which are not separated out at the NZLRI mapping scale, or it may be mapped in complexes with non-arable LUC units (e.g., VIe6, VIel5, VIIe2) on the valley sides. IIIe5 has a moderate to severe sheet and rill erosion potential under cultivation, and locally severe gully or streambank erosion potential where it occurs on colluvial ashes.

There is a greater potential for diversification in the northern part of the LUC unit, e.g., intensive dairying, with some horticultural use on gentler slopes. Areas further south, e.g., around Lake Rerewhakaaitu and the Galatea Basin, are significantly colder, but are suitable for dairying if supplementary winter fodder crops are grown. However, soils such as Pekepeke and Manawahe series are difficult to manage intensively. Although IIIe5 has a moderately high potential stock carrying capacity, exotic forestry is also an appropriate land use. Soil conservation measures such as contour cultivation and windbreak establishment would in any case be desirable.

LUC **unit IVe5 (8,350 ha)—**Figure 33

This LUC unit occurs on rolling to strongly rolling slopes mantled with deep Kaharoa Ash. Inventory factors recorded on IVe5 are very similar to those recorded on IIIe5, differing only in slightly steeper slopes. It has a fairly similar distribution, but occurs less commonly near the Bay of Plenty coast and more commonly further south, especially around the Galatea Basin. In the southern districts, colder winter temperatures, deeper Kaharoa and Tarawera ashes and steeper slopes mean that arable use is marginal and would not normally include horticulture. There is a greater incidence of erosion than in IIIe5, with a moderate to severe erosion potential under arable use and a slight potential even under pasture. Essentially, IVe5 has the same pastoral and exotic forestry potential and requires the same management techniques as IIIe5, except that more intensive soil conservation techniques are required under arable use.

LUC **unit VIe8 (6,700 ha)—**Figure 35

This LUC unit occurs on moderately steep to steep hill country where Kaharoa Ash mantles 'Mo' ashes over stable volcanic rock or greywacke. It is most common on the

***In this area, where Kaharoa Ash overlies Taupo Pumice and underlies Tarawera ash or Rotomahana Mud, LUC units from LUC subsuites 4b, 6a, 6b and 7b all intergrade. Hence the choice of any of these LUC suites can be somewhat arbitrary.**

Haparangi Rhyolite around the northern Rotorua lakes*. It also occurs on the hills surrounding the Galatea Basin where Kaharoa Ash overlies Taupo Pumice. In the southern part of the subsuite on the fringes of the Ikawhenua Range, where rainfall rises to 1600 mm p-a., the soils are podzolised (Ruakituri series).

In spite of long, moderately steep to steep slopes, VIe8 is generally not severely eroded, erosion being mainly sheet erosion on the Kaharoa and Tarawera ashes. It has the same potential stock carrying capacity as IVe5 but a greater erosion potential. Exotic forestry has high potential and is a good land use on this LUC unit apart from the indigenous forest areas around the northern Rotorua lakes, which are largely in scenic reserve. Minimising of bare ground exposure through fencing and stock control, and planting of steep faces, are considered essential soil conservation measures, while for forestry, compliance with the 'Forest Operations" guidelines (NWASCO 1976) is recommended.

LUC unit VIe 15 (28,250 ha)—Figures 32, 34

This LUC unit occurs on strongly rolling to short steep slopes mantled by Kaharoa Ash, over 'Mo' ashes which include significant lapilli, on unwelded rock types. It occurs solely on Rotoiti Breccia on the southern Kaharoa Plateau where it is the main non-arable LUC unit. About 60% of the soils are composite recent soils on yellow-brown pumice soils with a mantle of Tarawera ash or Rotomahana Mud. Remaining soils are mainly yellow-brown pumice soils. Vie 15 was often mapped on a complex landscape unit comprising valley sides, bottoms and dissected tops, indicated by a corresponding complex slope inventory. The difference in underlying rock types between this LUC unit and VIe8 appears to be reflected in physiography rather than present erosion, because neither the recorded intensity nor type of erosion is significantly different between the two LUC units. Possibly, the increased erodibility of its non-welded underlying lithology is masked by deep tephra or offset by generally shorter slopes. However, Vie 15 has been assessed as having more severe gully erosion potential.

VIe 15 is also similar to VIe8 in its land use pattern, although it has a greater proportion in exotic forest (centred on Rotoehu State Forest). It has very similar stock carrying capacity and exotic forest growth potential, and similar soil conservation requirements, except that gully control is also necessary. Exotic forestry is especially appropriate in the deeper, presently stable but potentially more erodible valley systems. As with VIe8, habitat conservation around the northern Rotorua Lakes is desirable.

LUC unit VIIe9 (5,300 ha)—Figures 36, 46

This LUC unit occurs in steep to very steep hill country and gullies where Rotoiti Breccia and associated ash and lapilli have eroded down to expose the underlying Mamaku Ignimbrite. There is a marked change in permeability between the underlying ignimbrite and the overlying breccia and associated tephras. This gives rise to locally severe and potentially widespread tunnel gully or 'piping' erosion within the very deep exposed tephras, as well as severe soil slip erosion. This erosion is not greatly influenced by the overlying Kaharoa Ash which is in any case often patchy or thin. VIIe9 occurs on the western Kaharoa Plateau, particularly within the Kaituna catchment (Nairn 1975), and has also been mapped on unconsolidated sediments in the Utuhina catchment near Rotorua.

Present land use consists of extensive grazing and some exotic forestry. Although there is potential for intensification of the present low grazing capacity, potential stock carrying capacity is only medium and then still with a continuing severe erosion risk. Careful management and intensive soil conservation and gully control measures are necessary for any pastoral use. On the other hand exotic forest growth potential is high to very high. Therefore, VIIe9 is more suitable for exotic forestry, although some areas will have severe access difficulties and would be more suitably retained in indigenous vegetation for catchment control. Application of the "Forest Operations" guidelines (NWASCO 1976) is essential.

"In this area, recent soils (Tarawera series, General Survey) were commonly recorded, but composite recent soils on yellow-brown pumice soils (e.g., Manawahe series) should be mapped because slopes on which VIe8 occurs generally have 10-15 cm Tarawera ash compared with 15-20 cm on the tops.

Fig. 32: LUC **subsuite 4b: General view. IIIe5 on redeposited ashes in foreground, VIel 5 on moderately steep scarp face on right and in background, and VIIe2 (LUC subsuite 4a) on steep scarp face at left. IIIe5 and IIIs4 on terrace tops (skyline). Pongakawa Valley, N68/987345 looking S.**

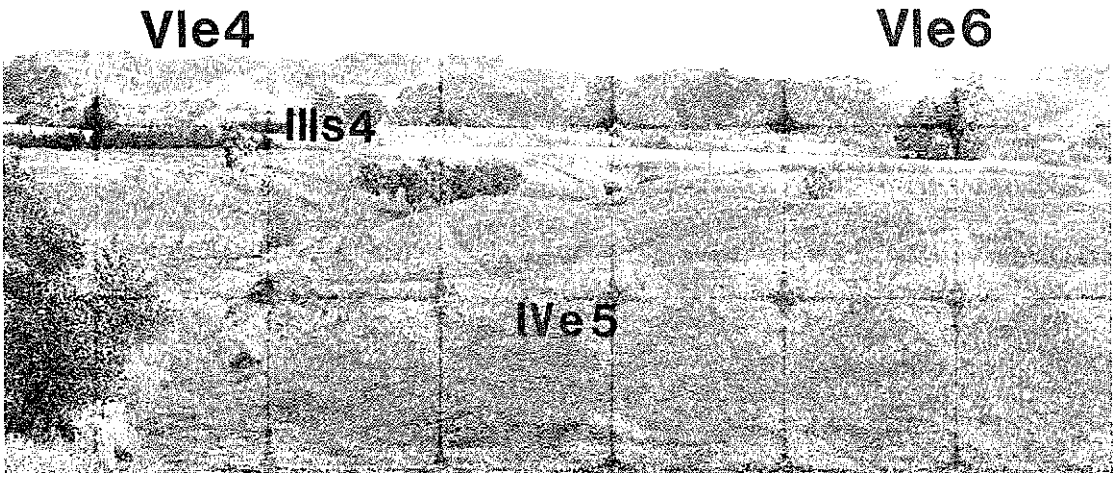


Fig. 33: LUC subsuite 4b: General view over northern Kaharoa Plateau. IIIs4 (flat terraces) and IVe5 (foreground) mapped on 15-30 cm Kaharoa Ash. Hills behind are VIe4, (LUC subsuite 4a), and VIe6 (LUC subsuite 4c). Otamarakau district, N68/064404 looking S.

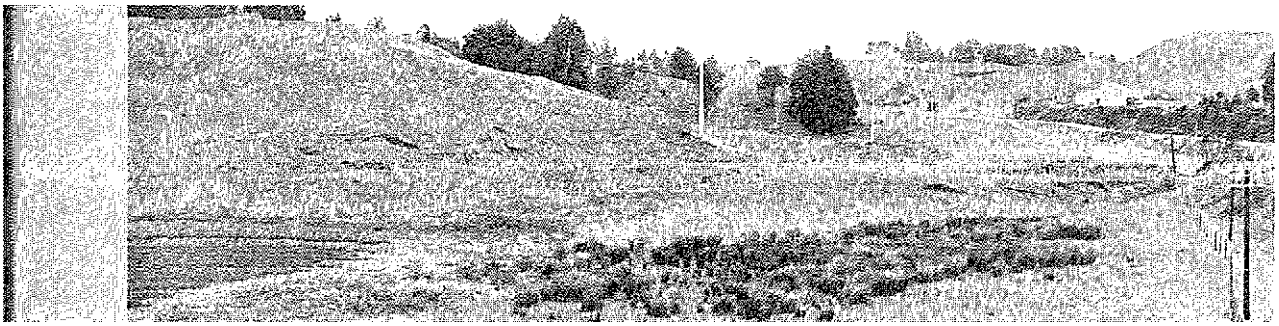


Fig. *Zh* I.L'C subsuite 4b: 111 e 5 on valley floor and terrace tops, and VIel5 on valley sides. Thin Tarawera tephras present in this area. Manawahe district, N68/110213 looking SW.

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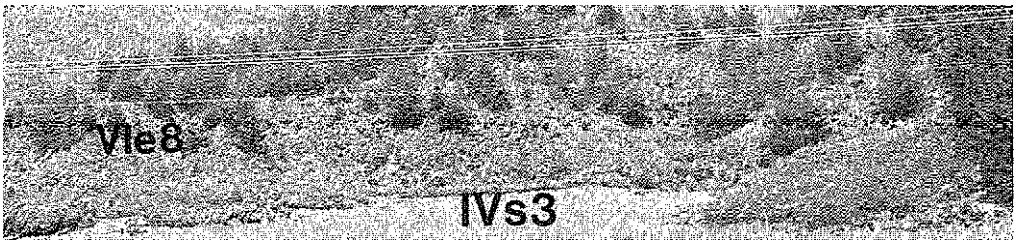

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Fig. 35: LUC subsuite 4b: IIIs4 on terraces in the Galatea Basin (foreground), IVs3 (LUC suite 3) on gravel fan and VIe8 on hill behind. Ikawhenua Range in background is VllelO (LUC subsuite 8a). Troutbeck Rd, Murupara district, N86/198635 looking SE.

Fig. 36: **LUC subsuite 4b: VIIe9 on. steep unstable hill country subject to severe soil slip and gully erosion. Historic erosion scars can be seen. Maungamangi Rd, Kaituna catchment, N67/821358 looking SE.**

LUC SUBSUITE 4c: KAHAROA ASH OVER LAPILLI

General

This subsuite occurs on hill country in coastal Bay of Plenty, where thin layers of Kaharoa and other surficial ashes cover deep 'Mo' tephras which include significant depths of interbedded lapilli from the Mangaone Lapilli Formation (Vucetich & Pullar 1969). This results in a distinctive erosion pattern characterised by deep-seated slip erosion. Mangaone Lapilli occurs widely in the Bay of Plenty but this subsuite was mapped only in areas where the lapilli appeared to have a significant effect on the erosion and landform pattern and land use capability, in spite of variable depth of soil-forming parent materials and variable underlying rock type.

The distribution of the subsuite is shown in Fig. 25. It occurs mainly in the hill country between the northern Urewera ranges and Whakatane, interrupted by the Whakatane and Waimana valleys. In this district the effects of the Mangaone Lapilli are very distinctive. Smaller areas occur west of the Rangitaiki Plains, as far as the Papamoa Hills near Te Puke. In these areas, the effects of Mangaone Lapilli are less distinctive and the recognition of its significance was subjective. LUC units from this subsuite mapped there are therefore similar to corresponding LUC units from LUC subsuites 4a and 4b.

The area of the subsuite is 59,250 ha, 28% of the Kaharoa LUC suite and 3.3% of the total area of the region. Because there are only two LUC units in the subsuite—VIe6 and VIIe5 (Fig. 37)—they are not individually described in the text, but are summarised in Table 16. They are distinguished from each other by slope. Small areas of arable land occurring within the subsuite area were included within LUC subsuites 4a or 4b.

The work of Pullar ***et al.*** (1978) on soils and land use of Whakatane Borough and environs, contains much general information about this subsuite, including a detailed land use capability survey of the Ngatiawa Land Development Block by P R Stephens.

Climate

The climate in this subsuite is generally very similar to that of LUC suites 1, 3 and 4a. Representative climate stations are Whakatane, Waimana, and Te Puke. South of Whakatane, rainfall increases and winter temperatures are lower. The high-intensity northerly and north-easterly rainstorms that characterise the coastal Bay of Plenty have an important effect on -he erosion pattern, but their effects are often very localised.

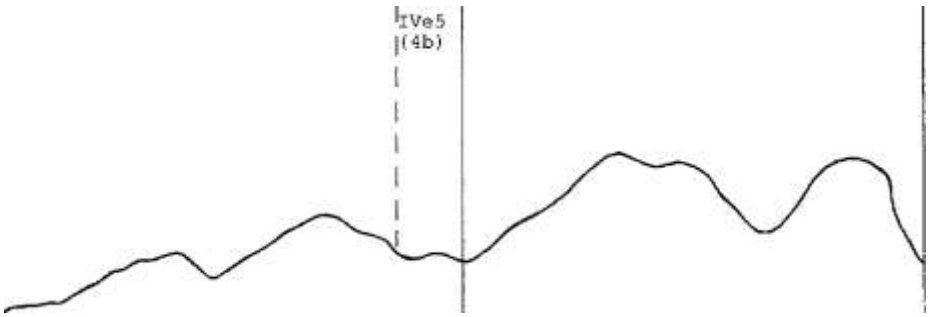
Physiography

The subsuite occurs on moderately steep to steep hill country, in most cases bounded by one or more faults and upthrust in relation to usually younger surrounding plains or volcanic flows. The Otamarakau, Matata and Hiwinui Hills have been surrounded but not overtopped by ignimbrite flows (Matahina or Rotoiti ignimbrites).

Rock Type and Soil Parent Material

The whole subsuite is mantled with considerable thicknesses of many 'Mo' tephras, particularly Whakatane, Oruanui and Rotoehu ashes and in the east, Pleistocene tuffs. Especially significant are various interbedded ash and lapilli beds of the Mangaone Lapilli Formation (used in the NZLRI as defined by Vucetich & Pullar (1969), but later subdivided by I loworth (1975)), which overlie Rotoehu Ash to a depth of 5-10 m. The 'Mo' ashes are overlain by up to 8 cm of Tarawera ash and up to 15 cm each of Kaharoa Ash and Taupo Pumice, all thinning to the north-east. None of these were thick enough to be recorded in the rock type inventory.

TABLE 16: LUC units on Kaharoa Ash over lapilli.

RELATED LUC UNIT (LUC Suite)	VIe6	VIIe5
		
LUC UNIT	32 150	27 100
AREA <ha)	E + F E E + D	F F + E F + G
SLOPES	SOILS	Tawhia Pukemaku Whakatane (Kaweka)
% MAP UNITS CON-TAINING EROSION	Whakatane Manawahe Oropi	Exotic forestry Undeveloped
PRESENT EROSION	80	1-2SS1; 1Sh,eSl,G
POTENTIAL EROSION CAPACITY (s.uJha)	1sSl,Sh,eSl	3sSl; 2eSl,Sh,G
PRESENT LAND USE	2sSl,eSl,Sh,G	Undeveloped Extensive grazing Exotic forestry
STOCK CARRYING	Grazing	6, 8, 10
SITE INDEX (m)	12, 13, 17	33-40
	33-41	

The underlying rock types in the subsuite comprise approximately equal parts of Matahina Ignimbrite (Matata Hills and western Raungaehe Range), undifferentiated Urewera Greywacke (western Whakatane Hills and northern Raungaehe Range) and various moderately consolidated mid-Pleistocene sands, silts, breccias, tuffs and Castlecliffian sandstones, collectively recorded as Us (eastern Whakatane Hills and coastal fringes). In the west, the Papamoa Hills are underlain by a complex mixture of Miocene to early Pleistocene sedimentary and volcanic rocks.

Soils

Nearly 90% of the subsuite was mapped using soils from the Whakatane Survey. The remainder (occurring west of the Matata Hills) was mapped using soil from the General Survey. Soils on 37% of the subsuite are classified as yellow-brown pumice soils (Whakatane series) and on 22% as composite recent soils on yellow-brown pumice soils. The Whakatane soils have properties intermediate between yellow-brown pumice soils to the west (e.g., Ohinepanea series) and yellow-brown loams to the east (e.g., Opotiki series) (W. Rijkse, pers. comm.). The distinctive nature of these soils was another reason why this subsuite was separately delineated. On most of the remaining areas, steepland soils related to yellow-brown pumice soils were recorded*. These occurred mainly on VIIe5.

Erosion

This subsuite differs from LUC subsuites 4a and 4b both in the severity and type of erosion. Erosion occurs more widely than on these other subsuites; map units covering 87% of the area have erosion recorded (slight severity on 81% and moderate severity on 6%), compared with 65% of the non-arable area in LUC subsuites 4a and 4b.

The most significant feature of erosion in this subsuite is that mass movement and fluvial erosion are of greater importance than surface erosion. Slip erosion is recorded on map units covering 76% of the area of the subsuite, and is of moderate severity on 5%, while sheet erosion is recorded on map units covering 43% of the area (slight severity only). Furthermore, slips in this subsuite are deeper than elsewhere in the region and frequently show some rotational movement and features of slumping. These features are characteristic of earth slip, as defined in the NZLRI erosion classification (Eyles, in press), although both soil slip and earth slip were recorded in the subsuite. Most areas were classified in erosion association P, although association Q would have been more appropriate for this type of erosion. Gully erosion is also significant in some map units.

The nature of slipping is thought to relate to changes in permeability between relatively permeable and relatively impermeable horizons, either at the top or within the Mangaone Lapilli Formation, or between Rotoehu Ash and weathered greywacke or older tephras such as clay beds of the Pahoia Tuffs. Failure takes place when permeable layers become saturated, the depth of slipping being related to the depth of the affected horizons (N. Ngapo, pers. comm.; P.R. Stephens, in Pullar ***et al.*** 1978). Failure processes in areas of the subsuite west of the Rangitaiki Plains have not been studied, but the relevant tephrostratigraphy is essentially similar.

Land Use and Land Management

Extensive sheep and cattle grazing is the most important land use on this subsuite, occupying about 30% of the area. Some dairying occurs on easier country around Ruatoki and Waimana and on the Matata Hills. Exotic forestry occupies about 10% of the area, mainly on the Raungaehe Range, with some agroforestry occurring in smaller blocks. The rest of the subsuite is undeveloped, with some minor indigenous logging in the east in areas being converted to exotic forest. Undeveloped land is mainly regenerating hardwood forest dominated by rewarewa and kamahi. Some podocarp-hardwood forest, and one block of podocarp-hardwood-beech forest at Matata, was also recorded. Indigenous forest occurs widely together with scrub in which manuka or five-finger are prominent species, and mosaics of

***Some steepland areas have traces of Tarawera ash. Note that areas mapped in the Whakatane Survey and in the NZLRI as Ngatiawa steepland soil are mapped in the Whakatane Borough Survey as Kaweka steepland soil.**

indigenous forest, scrub and unimproved pastoral land are common. Bracken is widespread. Several scenic reserves of regenerating hardwood forest occur near Whakatane and the Waimana Gorge, and the subsuite borders onto northern parts of the Urewera National Park.

Land use potential shows a clear difference between the two LUC units in this subsuite. VIe6, because of its easier slopes and lower erosion potential, is more intensively used and has a much greater potential for sheep, cattle and deer grazing. However, its stock carrying potential can only be realised with relatively intensive soil conservation practices such as appropriate grazing management to minimise the incidence of bare ground, gully control and open space planting of conservation trees. VIe6 also has a high to very high exotic forest growth potential.

VJIeS, however, has only a low stock carrying potential and a continuing severe erosion potential. Although, as demonstrated on the Ngatiawa Land Development Block, it can be farmed in conjunction with VIe6 subject to intensive soil conservation measures, VIIe5 is more suitable for exotic forestry which has a high although variable potential. Exotic forestry use should comply with the "Torest Operations" guidelines (NWASCO 1976).

Fig. :■'/: LUC subsuite 4c: VIe6 (right foreground) and VIIe5 (background), showing historic rotational slipping largely controlled through stock management and open planting of poplars. IIIwl (LUC suite 3) in valley. Ngatiawa Land Development Block, N69/468220 looking SE.

LUC SUITE 5: PODZOLISED YELLOW-BROWN **LOAMS**

General

This LUC suite has three diagnostic characteristics: firstly, a distinctive physiographic position on an extensive and elevated steep-sided ignimbrite sheet; secondly, a moderately deep cover of weathered tephra without significant depths of Taupo Pumice or more recent ashes; and thirdly, a wet and cool climate. While none of these factors are individually unique to the region, their combination, which gives rise to podzolised yellow-brown loams, is unique, and is responsible for a distinctive LUC suite in which versatility is low and agricultural development very limited.

The main part of the LUC suite occurs on the Mamaku Plateau, west and north-west of Lake Rotorua (Fig. 25). It also occurs on the tops of the Kaimai Range, which is continuous with the northern Mamaku Plateau, as far as the northern boundary of the region, where it correlates with adjoining areas in the Coromandel-Great Barrier Region. The area of the LUC suite is 87,150 ha, 4.9% of the total area of the region.

There are four LUC units: IIIe9, IVe9, IVel2 and VIell. Three of them form a continuum, divided according to slope, while the fourth, IVel2, is distinguished by the presence of rock outcrops. The LUC suite does not include steepland areas on the edges of the Mamaku Plateau or on the Kaimai Range, because these were included in LUC suite 8. However, the two LUC suites occur extensively together. LUC suite 5 grades into LUC suite 1 on the eastern side of Kaimai Range and into LUC subsuite 4a to the north of the Mamaku Plateau as the depth of Kaharoa Ash increases. In the south-west of the Mamaku Plateau, Taupo Pumice becomes significantly thicker and LUC suite 5 grades into LUC subsuites 7a and 7c.

Climate

The climate over this LUC suite is the most severe in the northern part of the region; it is characterised by high rainfall and cool winter temperatures. Both these features are largely a result of elevation. Annual rainfall is greater than 2000 mm over almost all the area, and reaches more than 2400 mm in higher areas towards the north. Rainfall is greatest between May and August. Many if not most winter days experience ground frosts, which can occur at any time of the year. Mean annual temperature at Mt Te Aroha, in the very north of the region, is 8C (Jane & Green 1983a) but climate records for the Mamaku Plateau are not available. The area is windy in comparison to the region as a whole. There are no representative climate stations.

Physiography

The major part of the LUC suite is located on the elevated ignimbrite sheet that forms the Mamaku Plateau. It is of generally low relief and sometimes flat, but differential weathering of the columnar jointed ignimbrite has left distinctive residual tors on large parts of the plateau (Healy 1982), while intervening hollows often have very restricted drainage, which has resulted in peat formation. The plateau ends in a series of steep or precipitous cliffs, particularly to the south and south-east. Elsewhere, streams that drain the plateau have dissected its margins and deep gorges penetrate far into the plateau.

To the north, the Mamaku Plateau joins the Kaimai Range which is more varied in relief and physiography. Within the Kaimai Range this LUC suite occurs on rolling to moderately steep hill tops, and on the Whakamarama Plateau (Healy ***et al.*** 1964b), an area of lower relief.

Rock Type and Soil Parent Material

This LUC suite is*mantled by tephras ranging in depth from 5-8 m to less than 1 m at the north of the region. Most of this mantle consists of weathered 'Mo' ashes, which are recorded in the rock type inventory throughout. Rotorua Ash is prominent in the east, where it is the basal tephra, while elsewhere it is underlain by undifferentiated brown tuffs or by

ashes from the Mangaone Lapilli Formation. These are coarse-textured in places but tephra of lapilli texture are insignificant. A feature of the older ashes on the Mamaku Plateau is the presence of tephric loess (Kennedy & Pullar 1977) which is of significant depth in places, but not separately recorded (see Chapter 3, p. 19). Andesitic ashes originating from outside the region are also present in the tephra column (Pullar & Birrell 1973b). Taupo Pumice, which is thinly present over the whole area, thickens rapidly up to 1.5 m in the southern portion, especially in the area east of Tokoroa where it is sometimes recorded as a rock type.

The underlying rock was recorded throughout the LUC suite as welded volcanic rock, mainly Mamaku and Waiteariki Ignimbrite, but also including limited areas of Minden Rhyolite, Waitawheta Dacite, and Beesons Island Volcanics*. The ignimbrites are poorly welded and rather pumiceous in places.

Soils

63% of the area of the LUC suite was mapped using soils from the General Survey. Most of the remainder was mapped using soils from the Rotorua Survey, with minor areas using soils from the Piako Survey.

The dominant soil group is podzolised yellow-brown loams (Mamaku, Waiteti and Mangorewa series). Most of these soils have shallow Kaharoa or Taupo ashes (up to 15 cm). The former thickens in the northern part of the Mamaku Plateau where podzolised yellow-brown pumice soils and composite yellow-brown pumice soils on yellow-brown loams are recorded (Oropi and Kaharoa series), but the influence of the Kaharoa Ash in this area may have been over-emphasised in the General Survey and some of these soils may be remapped as yellow-brown loams in future remapping. In the south-western part of the Mamaku Plateau, Taupo Pumice thickens rapidly and podzolised or weakly podzolised yellow-brown pumice soils are mapped in soil complexes with podzolised yellow-brown loams, the latter occurring on more strongly rolling slopes.

On the southern Kaimai Range, yellow-brown loams were mapped in the General Survey (as for LUC suite 1), but they occur in a rainfall regime which would be expected to give rise to podzolised soils. They are thus fairly similar to the Mamaku series soils but without Taupo Pumice. In general, all areas over 300 m a.s.l. were included in LUC suite 5. In the very north of the region, where the total tephra cover is significantly thinner, these soils grade into podzolised yellow-brown earths (Puketui Series). Steepland soils are rarely recorded in this LUC suite because steepland slopes are included in LUC suite 8. However, in closely dissected areas where the two LUC suites are mapped in complex, steepland soils related to yellow-brown loams also occur in complex with those discussed above. On the Mamaku Plateau there are frequent poorly drained hollows where peat formation occurs; the soils developed in these are described as a shallow peaty loam variant of Mamaku loamy sand (Rotorua Survey).

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H'osion was only recorded on map units covering 18% of this LUC suite. Most of this was minor sheet erosion, occurring on pasture under conditions of cool winds, high rainfall, and poor pasture growth or recovery after grazing. Soil slip was a minor erosion form on steeper slopes, occurring equally on forested and grassed areas. Minor streambank erosion was recorded in loosely consolidated, possibly redeposited, ashes in all LUC units of this IA C suite. Potential erosion is sheet, wind and rill, classified as erosion association P, mainly of slight to moderate severity.

La::-. Use and Land Management

This LUC suite occurs on one of the least developed and most sparsely settled parts of the region. Previous development has been based on logging of indigenous forest, which continues to the present, but present land use is becoming more diversified, including

***Beesons Island Volcanics has a considerably more varied lithology than the other rock types mentioned (Crippen & Eyles 1985) but, at the time of mapping was not recognised as a separate rock type.**

conversion to exotic forest and pastoral development for sheep and cattle farming and, more recently, deer farming. However, even now, more than 70% of the LUC suite has a dominantly forest cover. This is the highest proportion of all LUC suites except for LUC suite 8 which is predominantly in National Park or State Forest Park tenure. All classes of indigenous forest recognised in the NZLRI vegetation classification are found, including kauri forest in the north. The forest has, however, been highly modified, the most common classes being logged hardwood or podocarp-hardwood forest. Exotic forest covers about 12% of the area, while smaller areas are covered by mixtures of indigenous forest, scrub and/or grassland, especially pockets of logged forest within semi-developed farmland.

Less than 20% of the area is developed for pastoral use. Within this are areas of indigenous and exotic scrub, including gorse, blackberry, and Spanish heath, as well as rushes, toetoe, pampas and swamp vegetation in low-lying areas.

Land use trends are unclear. NWASCO (1982) recommended an expansion of development for pastoral use on arable LUC units, and for exotic forestry on non-arable LUC units. This recommendation is supported by a high potential stock carrying capacity on arable LUC units (although severely limited where there are rock outcrops) and high forestry site index rankings on well-drained portions of all LUC units. For pastoral use, an advantage of this area is that stock are not prone to facial eczema. Agricultural use requires careful maintenance of cover to minimise sheet erosion. On arable land, contour cultivation should be used, and windbreaks established.

Although catchment protection ***per se*** is not a major land use in this LUC suite, on the western edge of the Mamaku Plateau and in the southern Kaimai Range there are complexes of LUC units from this LUC suite and from LUC suite 8 in much steeper gullies draining into the Waihou catchment, where catchment protection is much more important. Development of all areas where these two LUC suites occur in a complex should therefore be undertaken only after careful consideration. In addition, most of the remaining unlogged forests and some of the modified forests are areas of very high conservation and wildlife value (Saunders 1983). Most of the LUC suite north of State Highway 5 lies within the Kaimai-Mamaku State Forest Park, and several large scenic reserves lie along State Highway 5 and the Putaruru-Rotorua railway line.

LUC Units on Podzolised Yellow-Brown Loams (Table 17)

LUC unit IIIe9 (6,400 ha)—Figure 39

This LUC unit occurs on gently undulating to rolling slopes on the Mamaku Plateau, which have a moderate wind and sheet erosion potential under cultivation. It occurs mainly on the central 'axis' of the plateau, especially in the area north of Mamaku settlement. In the north-east it is dissected by deep gullies, while in the south-west the depth of Taupo Pumice increases and IIIe9 grades into IIIe4 or IIIe6 (LUC subsuites 7a, 7b respectively).

IIIe9 has the most intensified land use pattern in this LUC suite, with about 50% developed for pastoral use; i.e., it is the only LUC unit which differs significantly from the general land use pattern described for the LUC suite. IIIe9 also has the greatest potential for intensification and diversification, including a limited horticultural potential for specialised crops, such as blueberries, which can withstand poorly drained soils. However, the area of IIIe9 is only about 6% of the LUC suite and this indicates how restricted the diversification potential of the LUC suite is.

LUC unit IVe9 (23,200 ha)—Figures 38, 39

This LUC unit occurs on rolling to strongly rolling slopes. It is distinguished from IIIe9 by its steeper slopes which result in a greater erosion risk under cultivation. It has a wider distribution than IIIe9, occurring throughout the Mamaku Plateau and occasionally on the tops of the Kaimai Range, but it is concentrated in the central Mamaku Plateau. The soils of IVe9 range from podzolised yellow-brown earths in the north, through podzolised yellow- brown pumice soils from Kaharoa Ash and podzolised yellow-brown loams of the central Mamaku Plateau, to podzolised yellow-brown pumice soils from Taupo Pumice in the south. However, the climatjc limitations over the LUC suite override these soil differences, so that only one LUC unit was recognised.

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TABLE 17: LUC units on podzolised yellow-brown loams.

LUC UNIT	Hle9	IVe12	IVe9	VIel 1	'"1
RELATED LUC UNIT (LUC Suite)					Vllel, (4a) Range on and VIIe4, (8c) slopes, around VIIIe3 (8a) gullies plateau
PHYSIOGRAPHY	Plateau tops	Plateau tops and slopes with rock outcrops	Rolling plateau slopes and range tops	Plateau slopes, hill-slopes and range tops	
AREA (ha)	6 400	11 900	23 200	45 650	
SLOPES	B B + C C	C C + D	C C + D C/D	E D + E D	
SOILS	Mamaku	Mamaku	Mamaku	Mamaku	
% MAP UNITS CONTAINING EROSION	Kaharoa 0	Bare rook 24	Kaharoa Mangarewa Rataroa 3	Oropi Waitekauri Whakamarama 30	
PRESENT EROSION	0	ISh	ISh	1-2Sh; lsSl	
POTENTIAL EROSION	0 (2W)	lSh,W(2-3Sh,W,R)	lSh,W(2-3Sh,W,R)	2Sh,sSl	
PRESENT LAND USE	Sheep, cattle, deer Exotic forestry Indigenous forestry Undeveloped	Undeveloped Sheep, cattle, deer Exotic forestry Indigenous forestry	Undeveloped Sheep, cattle, deer Exotic forestry Indigenous forestry	Undeveloped Sheep, cattle, deer Exotic forestry Indigenous forestry	
STOCK CARRYING CAPACITY (s.u./ha)	14, 20, 25	14, 18, 23	14, 18, 23	13, 16, 19	
SITE INDEX (m)	27-31	24-31	24-31	25-31	

IVe9 is subject to very slight sheet erosion but has a potential for moderate to severe surface erosion under cultivation. It has a predominantly indigenous forest and scrub vegetation, with only about 12% developed for pastoral use and 14% for exotic forest. However, its potential stock carrying capacity is high and the forest site index, although variable, is high in places. Arable potential is probably limited to restricted root and green fodder cropping.

LUC unit IVel2 (11,900 ha)—Figures 38, 40

This LUC unit occurs on rolling to strongly rolling slopes on the Mamaku Plateau interspersed with bluffy ignimbrite pillars. It has been mapped mainly in the central Mamaku Plateau, with smaller areas extending to the north. It forms a continuum with both IIIe9 and IVe9 and is distinguished from them only by the presence of the pillars, which severely restrict arable capability. Although the area between the rock pillars may have the same capability as IIIe9 or IVe9, on a farm scale the LUC unit is only marginally arable. In all other respects IVel2 is similar to the portions of IIIe9 and IVe9 which occur in the same areas.

LUC unit VIe11 (45,650 ha)—Figures 38, 41

This LUC unit occurs on strongly rolling to moderately steep hill slopes throughout the LUC suite. It comprises over half of the total area of the LUC suite, and is especially common in the Kaimai Range, occurring to the northern boundary of the region. It is similar to IVe9, apart from its steeper slopes. The full range of soils discussed on p. 87 is recorded on VIell, although, because of the steeper slopes, Kaharoa and Taupo ashes tend to be thinner and therefore podzolised yellow-brown pumice soils are rarely recorded.

VIell has a moderate soil slip and sheet erosion potential under pastoral use, and a lower potential stock carrying capacity than the other LUC units in the LUC suite. However, the forest site index is medium to high; therefore development would appear to be more suitably directed to exotic forestry than to pastoral use. However, the difficulty of retaining plant cover on steeper ground in this relatively severe climate, and the importance of off- site factors (see p. 88), require careful consideration of all development strategies on the LUC unit.

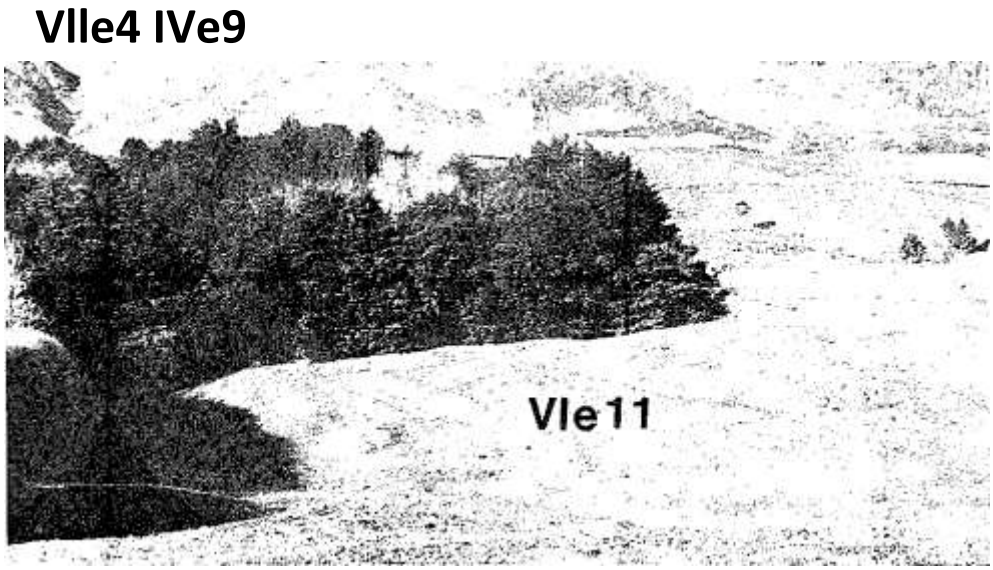

Fig. 38: **LUC suite 5: General view over northern Mamaku Plateau to Otanewainuku in left background. Foreground predominantly VIell, with IVe9 and IVel2 on forest—covered plateau; VIIe4 (LUC subsuite 8c) in gully behind trees. Hanga Rd, Kaimai district, N66/442364 looking SE.**

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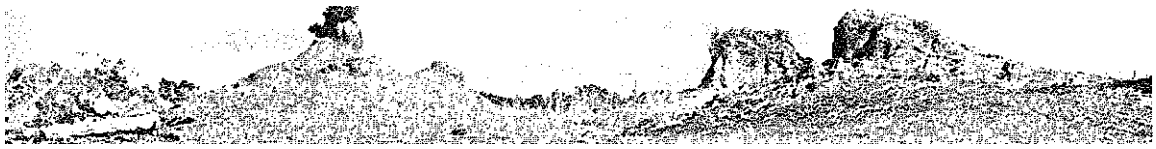
Fig. 39: LUC suite 5: **IIIe9 (foreground) and IVe9 (background). Oturoa Rd, Mamaku Plateau,** N76/567157 **looking** NE.



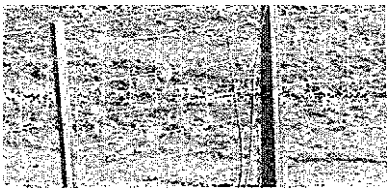


Fig. 40: LUC suite 5: IVel2 with characteristic ignimbrite pillars. Oturoa Rd, N76/567163 looking

left **j w.**
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Fig. 41: LUC suite 5: VIe11. Typical land use of low-producing pasture, cutover podocarp-hardwood forest and scrub. Note retired watercourse on right. Oturoa Rd, N76/602168 looking S.

LUC SUITE 6: RECENT TEPHRAS

This LUC suite is characterised by a soil parent material of volcanic tephra which is not more than a few hundred years old. The soils formed on these tephra, although differing widely in chemical composition, have the common feature of limited horizon development, which distinguishes them from soils formed on more weathered tephras. The degree of horizon development, erodibility, and variability in natural fertility of these soils are all reflected in land use capability.

There are two widely separated sources of the recent ashes significant in this LUC suite: the Tarawera eruption of 1886, and the eruptions of Mts Ruapehu and Ngauruhoe over the last 1800 years. Ejecta from the Tarawera eruption are grouped together as the Tarawera Formation (Healy ***et al.*** 1964a), containing two members: Tarawera Ash and Lapilli, and Rotomahana Mud. Tarawera Ash and Lapilli, which is basaltic, gives rise to coarse-textured soils which have low moisture-holding capacity and are very erodible. Rotomahana Mud is a much finer textured, hydrothermally altered, rhyolitic tephra and has weathered more rapidly, giving rise to comparatively fertile soils. These two tephras contrast with Ngauruhoe Tephra (Topping 1973), an andesitic ash originating from Mts Ruapehu and Ngauruhoe. High elevation and a harsh climate have resulted in very slow soil development, sparse vegetation and high erosion potential.

There are three subsuites in this LUC suite, defined according to the presence of the three tephras described above (Fig. 42). The subsuites generally occur where their diagnostic tephra is greater than 15 cm deep, because, at shallower depths, the properties of these tephras become less important to land use capability, relative to those of the underlying tephrr.s.

The three subsuites strongly contrast in some soil properties, landforms, erosion pattern, vegetation cover, and land use. They are described separately in the following sections.

LUC SUBSUITE 6a: TARAWERA ASH AND LAPILLI

The definitive characteristic of this subsuite is the presence of Tarawera Ash and Lapilli (Healy ***et al.*** 1964a) as a soil parent material. It gives rise to coarse-textured, excessively drained, erodible and rather infertile recent soils which severely restrict agricultural versatility.

The distribution of this subsuite, centred around Mt Tarawera and the Okataina Volcanic Centre, is shown on Fig. 42a. It occupies an area of 82,950 ha, 65% of the area of the LUC suite on recent tephras, and 4.7% of the total area of the region. There are four LUC units in the subsuite: IIIs5, IVsl, VIe20 and VIIe8. They are differentiated according to slope and soil texture. No LUC subclass IVe unit was recognised because all rolling or steeper slopes were classified as non-arable due to the erodibility of the Tarawera tephra. Steepland areas, mainly LUC class VIII, on Mt Tarawera and in isolated gullies, were included in LUC subsuites 8a, 8c or 4b, and small areas of rolling slopes on the top of Mt Tarawera were included in LUC subsuite 6c. Related LUC units with inclusions of Tarawera ash* include IIs2 and IVs3 (LUC suite 3), Vie 12 (LUC subsuite 7h) and IVe5 and Vie 15 (LUC subsuite 4b).

Climate

The climate over this subsuite is generally mild and moist. Temperatures are moderate, although mild ground frosts may occur throughout much of the year, and summer ground temperatures may be particularly high because of the high radiation absorbance by the dark coloured Tarawera lapilli. This results in severe summer soil moisture deficits. The representative climate station is Tarawera Forest.

[T]In several instances throughout this bulletin the informal term 'Tarawera ash' has been used in preference to the formal name Tarawera Ash and Lapilli when referring to generally finer basaltic tephra from the Tarawera Formation occurring at some distance from source.

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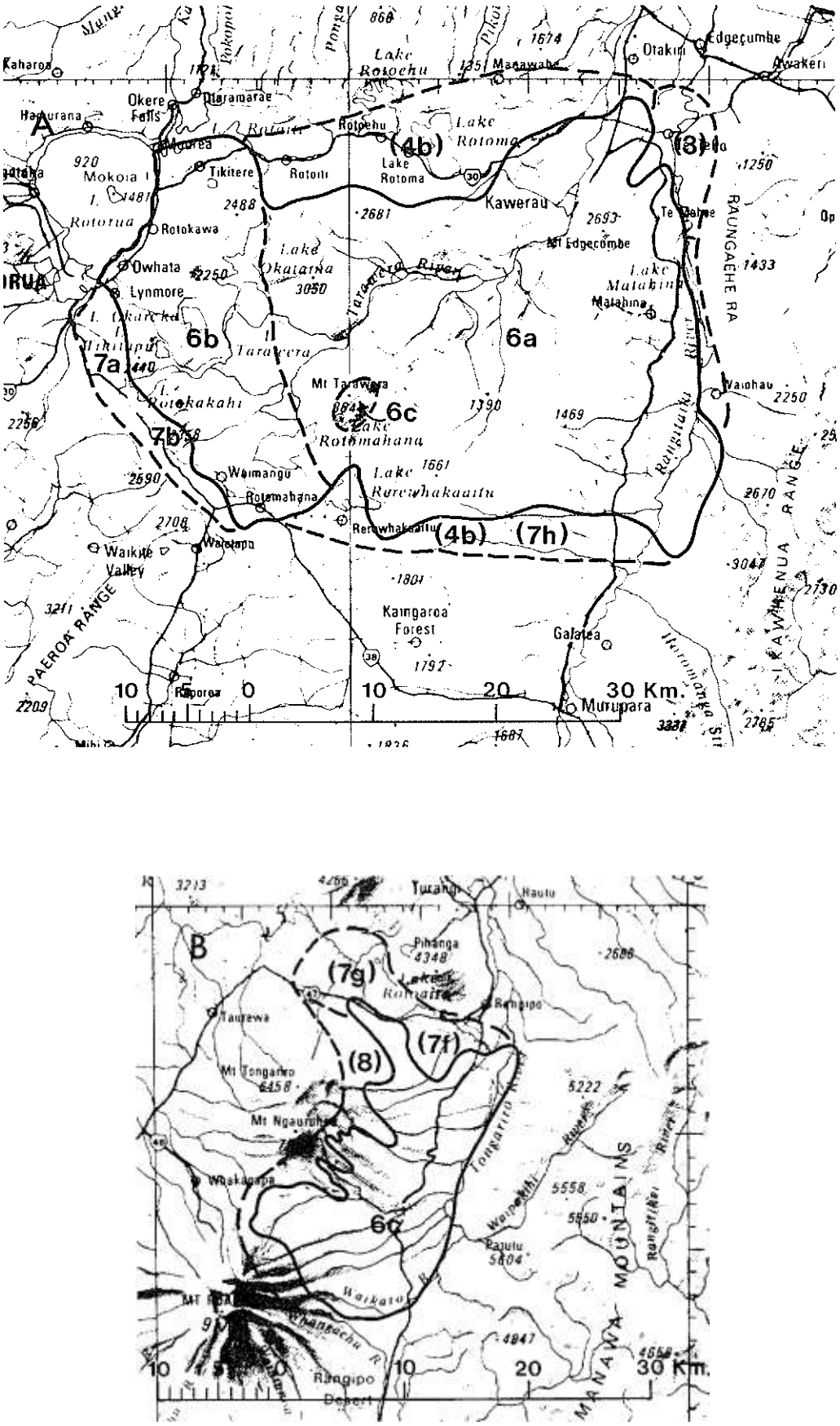

Fig. 42: **Distribution of LUC suite 6 on recent tephras, in the Rotorua district (Fig. 42a) and the Desert Road area (Fig. 42b). Areas marked 6a, 6b and 6c show Tarawera, Rotomahana and Ngauruhoe subsuites respectively. Dotted lines and numerals in brackets shown areas of gradation into other LUC subsuites.**

Physiography

The subsuite occupies a volcanic landscape within the Taupo Volcanic Zone, comprised of the following elements:

a) The steep rhyolitic dome of Mt Tarawera (Cole 1970a).
b) Smaller rhyolite domes of the Okataina Volcanic Centre, generally flat-topped or gently rounded but with short steep sides and intervening gullies.
c) The northern tip of the Matahina ignimbrite plateau, flanked by deposits of Rotoiti Breccia. This unit generally comprises rounded hills but is more gently rolling in the east and more deeply dissected in the south and on the flanking breccia country. It is pierced by the andesitic cone of Putauaki (Mt Edgecumbe).
d) Fans and terraces along the Tarawera River valley, adjoining Lake Rerewhakaaitu, and around the fringes of the southern Rangitaiki Plains.

Nearly 70% of the subsuite is rolling to moderately steep.

Rock Type and Soil Parent Material

The subsuite is characterised by great depths of surficial tephras: their combined depth is more than 20 m over most of the area, of which Tarawera Ash and Lapilli occupy only the top 1-2 m (Cole 1970a, b). It was recorded as a rock type over the whole subsuite except for minor steepland areas, and is underlain by deep Kaharoa Ash, 'Mo' ashes, and Mangaone Lapilli. The last usually had to be omitted from the inventory because of the NZLRI convention of recording no more than three rock types in a stratigraphic sequence, but may be significant in the initiation of mass movement erosion on steeper land (see VIIe8).

The underlying local basement rock is mainly rhyolite (Vo), although Rotoiti Breccia and small areas of unconsolidated material at the edges of the Haparangi Rhyolite were also recorded (as Ft). On some of the river valleys, fans and plains, redeposited ashes were mapped **as** Tp.

Soils

73% of the area of the subsuite was mapped using soils from the Whakatane Survey, and the remainder using soils from the General Survey. The soils are dominantly recent soils derived from Tarawera Ash and Lapilli (Tarawera and Kawerau series), or related soils. Where the Tarawera tephra are thinner at the periphery of the subsuite, composite recent soils on yellow-brown pumice soils were recorded; those occurring within the Tarawera subsuite had 18-27 cm coarse Tarawera ash (Matahina series) while those soils with only slightly thinner but distinctly finer Tarawera ash (Manawahe series) were included within LUC subsuite 4b on Kaharoa Ash. The northern boundary of the Tarawera subsuite thus crosses a continuum of soil depth and texture, and differences between LUC subsuites 6a and 4b in this area are small. Steepland soils related to yellow-brown pumice soils occur on about 15% of the subsuite.

In general, soils within the subsuite are coarsely textured, excessively drained and generally low in nutrients, although rapid surface weathering has occurred.

Erosion

Slight erosion was recorded on map units covering 17% of the subsuite, and moderate erosion on map units covering 5%. The main erosion types were sheet or soil slip, with minor gully erosion on the hill country, and minor (but locally severe) streambank erosion along river terraces. Most of the erosion was assessed as slight, but moderate to severe sheet erosion occurs on some steeper npn-forested land. Most of the area was classified as belonging to erosion association P, with association R occurring on some of the flat land.

I here is a marked difference in the erosion pattern between pastoral and forested land. About half of the area with a dominantly pasture cover had sheet erosion recorded, while less than 20% of dominantly scrub or forest-covered land had any erosion recorded. Almost all erosion was mass movement or fluvial (soil slip or gully). More mass movement erosion was recorded in indigenous than in exotic forest, reflecting the fact that much of this erosion

occurs on the steep sides of the rhyolite domes, which still have a largely indigenous forest cover. Soil texture is also a significant factor in the incidence of erosion because areas with coarser Tarawera lapilli are more seriously affected by erosion than areas of finer ash.

Land Use and Land Management

Present land use is dominated by exotic forestry, with two major private forest plantations covering nearly 50% of the area. Other land uses include sheep and cattle farming and minor dairying and horticulture, which together cover about 20% of the subsuite. Undeveloped land covers about 30%, comprising indigenous forest, indigenous scrub and forest-scrub mixtures dominated by scrub hardwoods. Undeveloped scrubland not being cleared for exotic forestry is undergoing rapid succession towards forest (Timmins 1983). There are several large scenic reserves, mainly adjacent to Lakes Tarawera and Okataina and the Tarawera River. Recreational use is high.

Potential land uses show a marked difference between flat land where a certain amount of diversification is possible, and sloping land where long-term pasture management is extremely difficult and subject to a significant erosion risk. However, exotic forestry potential is high over the whole subsuite, although somewhat variable on steeper land, where forestry operations should conform to the "Forest Operations" guidelines (NWASCO 1976).

In pastoral areas weed infestation is a serious problem and is difficult to control by grazing, because once the sward is broken revegetation is extremely difficult and sheet erosion in the loose lapilli is a continuing problem. Therefore, although limited areas with finer textured soils, e.g., around Kawerau, can be successfully farmed under good management, pastoral agriculture is likely to become a minor land use except on the best flat land. All areas are subject to severe drought under pasture and lucerne is useful in pastoral management. Exotic forestry is rarely limited by drought because tree roots can reach beneath the Tarawera tephras into tephra layers with greater water-holding capacity.

In summary, the Tarawera subsuite is a good example of an area which, although well suited to one type of land use, has a low overall versatility because of its physical limitations.

LUC Units on Tarawera Ash and Lapilli (Table 18)

LUC unit IIIs5 (4,500 ha)—Figure 44

This LUC unit comprises flat to gently undulating areas with soils derived from Tarawera Ash and Lapilli over pumiceous alluvium (Kawerau series). Areas of finer-textured composite recent soils on yellow-brown pumice soils with a thin mantle of Tarawera ash have been included in IIs2 (LUC suite 3). It occurs mainly on the southern Rangitaiki Plains but was also mapped on terraces around Waiohau and south of Lakes Rotoehu and Rotoma. In the latter areas, IIIs5 also includes Kopuriki soils, and soils which, although mapped as Tarawera gravels in the General Survey, were considered to be closer to Kawerau soils in texture.

This is the only LUC unit in the subsuite which has a significant potential for diversification. Horticulture (especially asparagus growing), orcharding and maize cropping are all land uses which, while extremely limited at present, have considerable potential if irrigation is provided. However, the moderately coarse-textured and droughty nature of the Kawerau soils limit the versatility of IIIs5 compared to adjacent LUC units on the Rangitaiki Plains (e.g., IIs2). Deep-rooted crops are likely to perform better than shallow-rooted ones. Potential stock carrying capacity and exotic forestry potential are both high or very high.

LUC unit IVsl (9,900 ha)—Figure 43

This LUC unit occurs on flat to undulating slopes with coarse-textured soils formed on deep Tarawera Ash and Lapilli over a variety of rock types usually including redeposited ashes. It occurs mainly in the Tarawera Valley* and on the fans between Lakes Rerewhakaaitu and Rotomahana and Mt Tarawera, with isolated map units elsewhere. IVsl differs from IIIs5 chiefly in topsoil texture (gravel compared to coarse sand). The coarse texture and excessive drainage of the dominant Tarawera soils reduce the versatility of IVsl to an extent

***A11 areas in the Tarawera Valley upstream of Kawarau were mapped as IVsl, including about 2,000 ha on Kawerau soils (normally included in IIIs5) because Tarawera tephras in this area are thicker and slightly coarser than on the Rangitaiki Plains where most of the Kawerau soils occur.**

TABLE 18: LUC units on Tarawera Ash and Lapilli.

LUC UNIT	IIIs5	IVsl	VIe20	VIIe8
RELATED LUC UNIT (LUC Suite)	IIs2 ' (3) 1	jlVs3 ' '(3) I II		,VIIIe3 1 (8a)
PHYSIOGRAPHY	1 1 Southern Rangi-taiki Plains 1 Fine 1 Tara-1 wera ' ash | 1 1	I I I I River valleys and flats near Mt Tarawera I I I Lowest riverj levelj I I I I j I -	Breccia and rhyo. country. Slopes ignimbrite plate*	1 Gullies | and Lite hill i steep- / of 'lands / 1 /
AREA (ha)	4 500	9 900	30 650	37 850
SLOPES	A A +" B	A A + B B	C D D + E	E D + F F
SOILS	Kawerau	Tarawera Kawerau	Tarawera Matahina	Tarawera Matahina Haroharo
% MAP UNITS CONTAINING EROSION	0	6	12	36
PRESENT EROSION	0	lSb	ISh	l-2Sh,sSl; 1G
POTENTIAL EROSION	0 (1W)	0 (1W)	2Sh; 1G	3Sh,G; 2sSl
PRESENT LAND USE	Dairying Sheep & cattle Exotic forestry Horticulture	Exotic forestry Sheep & cattle Undeveloped	Exotic forestry Undeveloped Sheep & cattle	Exotic forestry Undeveloped Extensive grazing
STOCK CARRYING CAPACITY (s.u./ha)	14, 19, 25	11, 15, 20	5, 5, 5	-, -, o
SITE INDEX (m)	37-41	30-41	27-40	27-39

such that arable use is marginal (it is not suitable for maize cropping). However, present and potential erosion under pastoral or forestry use is assessed as negligible.

The dominant land use is exotic forest, with pastoral use, including minor root and green fodder cropping, occupying only about 20% of the area. Grazing potential is high and exotic forestry potential mainly very high, although it is slightly depressed on lower river terraces. The distribution of the LUC unit, largely within Tarawera Forest, would however suggest that future land use will tend towards exotic forestry.

LUC unit VIe20 (30,650 ha)—Figures 43, 44

This LUC unit occurs throughout the subsuite on rolling to moderately steep slopes on Tarawera Ash and Lapilli which overlie deep tephras on a variety of rock types. Where Tarawera Ash and Lapilli is thick, Tarawera soils are mapped; where it is shallower, Matahina soils (composite recent soils on yellow-brown pumice soils) are mapped. Both these soils are coarse textured, infertile and subject to drought. On the northern edge of the subsuite where Tarawera ash becomes thinner and finer, VIe20 grades into Vie 15 (LUC subsuite 4b) on Manawahe soils (see p. 95). Only small areas are at present affected by erosion, mainly slight sheet occurring on pastoral areas, but there is a potential for moderate sheet and gully erosion.

Exotic forest occupies just under 50% of the area, with the remainder divided between indigenous forest, pasture and scrub. Future development towards exotic forestry is recommended (NWASCO 1982) because of the very low present and potential stock carrying capacity, although this ranking may be rather pessimistic on easier country towards the edge

of the subsuite, e.g., north of Kawerau (N. Ngapo, pers. comm.). Any pastoral use requires very careful management aimed at maintaining a complete pasture cover. Cattle grazing is not recommended.

LUC **unit VIIe8 (37,850 ha)—**Figures 43, 45

This LUC unit occurs on moderately steep to steep slopes throughout the subsuite. It is drought-prone and infertile country subject to severe sheet and gully erosion. Because the Tarawera Ash and Lapilli is of variable depth (related to steepness, aspect and distance from source), a variety of hill soils and steepland soils are mapped. Present erosion is also variable; as well as sheet erosion, soil slip and gully erosion become significant as surficial ashes thin out and the underlying rock types assume greater significance. Soil slip and gully erosion are often initiated at the interface between Mangaone Lapilli and underlying tephras.

The main vegetation cover on this LUC unit is exotic and indigenous forest, with some scrub and mixed pasture and scrub. Present pastoral use is very limited and stock carrying capacities were not assessed for the regional LUC extended legend. It is anticipated that exotic forestry will become the dominant land use, although poor accessibility, variable forest growth potential and erosion risk mean that erosion control and catchment protection is the most appropriate land use in places.

Fig. 43: LUC subsuite 6a: General view of subsuite near Lake Tarawera, showing dominant exotic forestry use (indigenous vegetation retained in gully at right). Tarawera Forest, N77/096995 looking NW.

Fig. ·.· i.UC subsuite 6a: IIIs5 with horticultural use (asparagus). Hills behind are VIe20. Onepu Springs Rd, Kawerau district, **N77/195142** looking **E.**

. J: LUC subsuite 6a: VIIe8, showing sheet erosion and scrub reversion problems associated with pastoral use on moderately steep slopes. Matahina district, N86/060860 looking N.

LUC SUBSUITE 6b: ROTOMAHANA MUD

General

This subsuite is characterised by a mantle of Rotomahana Mud (Healy ***et al.*** 1964a), which differs markedly in texture and chemical properties from the adjacent, more extensive Tarawera Ash and Lapilli deposit. The texture, fertility, drainage and erosion characteristics of the resulting soils are quite distinct, not only from the recent soils formed on Tarawera Ash and Lapilli, but also from the surrounding yellow-brown pumice soils formed on Kaharoa Ash and Taupo Pumice. The contrast between this subsuite and the Tarawera subsuite is particularly vivid because the soil properties have resulted in an entirely different land use pattern.

The subsuite occurs in the eastern Rotorua district (Fig. 42a). Its area is 21,450 ha, 17% of the LUC suite on recent tephras and 1.2% of the total area of the region. There are five LUC units, differentiated mainly by relief: IIs3, IIIe3, IVe3, VIe7 and VIIe3. The subsuite is bounded by LUC subsuites on Kaharoa Ash (4b) to the north, Tarawera Ash and Lapilli (6a) to the east, and Taupo Pumice (7a, 7b and 7h) to the south and west. Within the subsuite are small inclusions of steepland areas (LUC subsuite 8a), alluvial areas (LUC suite 3) and redeposited ashes mapped as Taupo flow tephra (LUC subsuite *If).*

Climate

Annual rainfall is between 1400 and 2000 mm, and is fairly well distributed through the year although slight summer moisture deficits are common. June and July are rather cold and frosty, especially in the south. The representative climate station is Rotorua Airport.

Physiography

The subsuite occurs within the Taupo Volcanic Zone, in several distinct physiographic environments:

a) Terraces and alluvial valleys within the Rotorua Basin below approximately 360 m a.s.l. Most of these surfaces date from pre-14,700 yr BP (Kennedy ***et al.*** 1978).
b) Recent surfaces fringing the lakes within the subsuite, formed from materials eroded from surrounding hills since the Tarawera eruption (mapped as Tp).
c) Hill country in the central part of the subsuite, formed on the eastern remnants of the Mamaku ignimbrite sheet through which rhyolite domes have been extruded. These latter rise to 758 m at Mt Whakapoungakau.
d) Broken surfaces on breccia flows in the north and south of the subsuite; Rotoiti Breccia stretching from Mt Whakapoungakau down to Lake Rotoiti, and Earthquate Flat Breccia in the south-west. Several steep-sided small lakes occur within the breccia flows.
e) The north-west extremities of the Kaingaroa Plateau occurring around Lake Rerewhakaaitu.

The subsuite occurs predominantly on hill country, with only 7% of its area (mainly the first two situations above) being flat or undulating. Very steep slopes are included in LUC subsuite 8a. Most slopes are fairly short.

Rock Type and Soil Parent Material

Rotomahana Mud, a pale grey ash or mud, is present over the whole area at depths ranging from approximately 8 to 100 cm. It is recorded in the rock type inventory over about 55% of the subsuite, being thinner than 15 cm on the western edge and on steeper slopes throughout. On the eastern margins of the subsuite it contains some Tarawera lapilli. Where Rotomahana Mud was not thick enough to be recorded in the rock type inventory, older 'Mo' tephras were recorded as the surface rock type. The tephras include redeposited ashes which, because a period of intense erosion followed the 1886 Tarawera eruption, are thick in many valleys and flat areas.

Beneath Rotomahana Mud, the whole subsuite, except for the most recent lake deposits, is mantled by 5-10 m of tephras from the Rotorua Sub-group. Kaharoa Ash and Taupo

Pumice (in the south only) are also present; the former ranges from 10 to more than 100 cm deep, and significantly influences soil properties in the north of the area, where it is comparatively deep and Rotomahana Mud comparatively shallow.

Welded volcanic rock, occurring as Haparangi Rhyolite, Mamaku or Rangitaiki Ignimbrite, is the local basement rock over about three-quarters of the area. Rotoiti or Earthquake Flat Breccia (both mapped as Ft) underlie about 10% of the area, and lacustrine and alluvial deposits around the lakes (mapped as Us) are recorded over a similar area.

Soils

75% of the area of the subsuite was mapped using soils from the Rotorua Survey, and the remainder using soils from the Waiotapu Survey, as well as very small areas from the General Survey. The most important soils are recent soils from Rotomahana Mud (Rotomahana series), which were recorded on 64% of the subsuite. These soils have a relatively high clay content and nutrient status, which is attributed to hydrothermal preweathering (Gibbs 1980), but do not have good internal drainage, are subject to cracking and erosion, and are also slightly susceptible to drought because of the low water-holding capacity of the underlying Taupo and Kaharoa ashes. Generally, however, they are quite distinct from surrounding yellow-brown pumice and composite recent soils on yellow-brown pumice soils because of the surficial Rotomahana Mud, which is significant even as a thin mantle because of its ability to supply nutrients to shallow-rooting grasses. Where the Rotomahana Mud is less than 20 cm thick the soil is classified as a composite recent soil on yellow-brown pumice soil (Rotomahana series, shallow phases). Other composite recent soils on yellow-brown pumice soils were recorded where the underlying Kaharoa Ash is thicker (Rotoiti series). Related steepland soils (Okareka and Paretotara series) occur over 22% of the area.

Erosion

Slight erosion was recorded on map units covering 44% of the subsuite and moderate erosion on map units covering 8%. Gully and sheet erosion are the most important types, each affecting map units covering just under 30% of the area. They are commonly recorded together. However, gully erosion has been more significant historically and is much more prevalent, especially at moderate severity. Tunnel gully erosion is often associated with sheet erosion and is recorded over 12% of the area, while soil slip is comparatively minor. Small areas affected by slump and streambank erosion, although this may be locally severe (Stephens ***et al.*** 1976), have not been recorded at the scale of the NZLRI.

Erosion may occur on all rolling or steeper land because of the soil properties discussed above; steepland areas cleared of woody vegetation are particularly prone to erosion. Severe gully and rill erosion occurred after the 1886 Tarawera eruption. Terraces and fans accumulated rapidly in valley floors and on lake edges, and further recent erosion, such as that described by Stephens ***et al.*** (1976), is associated with these deposits.

Land Use and Land Management

The present land use pattern on this subsuite consists of about 30% sheep and cattle breeding or fattening, 15% dairying, 2% horticulture (mainly orcharding), 12% exotic forestry and about 40% undeveloped. About 75% of the undeveloped land is covered with indigenous forest and scrub in various successional stages following the Tarawera eruption (Nicholls 1963). Milling of podocarp-hardwood forest has been a continuing minor land use. The remainder of the undeveloped land has a scrub cover, mainly indigenous, but including significant gorse, occurring in conjunction with extensive pastoral or exotic forestry use. The subsuite thus already has a diversified land use pattern, but considerable further diversification and intensification is possible.

On arable land, horticulture, orcharding, dairying and stock fattening are possible, with large increases in stock carrying capacity also achievable. The proximity of this land to Rotorua City will encourage intensification, but a proviso to arable use is that the long-term response of the soil to cultivation is not yet known. Careful management is necessary to minimise erosion on rolling land and to ensure that soil structure is maintained; where Rotomahana Mud is thicker than 20 cm this is very difficult, so these areas are unsuitable

for intensive horticulture. A problem with dairying and cattle rearing is the alternation of winter pugging and summer drying of the Rotomahana soils which leads to cracking of the fine-textured soils.

On the non-arable land, moderate diversification and intensification is also possible on strongly rolling and moderately steep slopes. On this land there is a moderately high potential stock carrying capacity due to the fertility of the soil, but erosion is a continuing risk, and soil conservation measures aimed at gully control and minimising bare ground exposure are essential. Exotic forestry, centred on Whakarewarewa State Forest Park, is an established land use and is presently expanding in the south of the subsuite. Exotic forest site indices are generally medium to high. Agroforestry is a further means of diversification, as shown by the success of trials at Tikitere.

On steeper land there is a severe erosion potential and production potentials are not high. Much of this land is covered in indigenous forest and scrub and has very high habitat conservation, recreation and scenic values which in an area so close to the tourist centre of Rotorua are also economically important. Much of this land, together with steepland (LUC suite 8) areas around the lake edges, has scenic reserve tenure (including the whole of the Lake Okataina margin), and preservation of most of the remaining uncommitted land would be a suitable land use.

In summary, this small and compact area has an exciting potential for a diversified and highly productive land use pattern that combines both active and passive land uses. Such use could be a model for the rest of the region.

LUC Units on Rotomahana Mud (Table 19)

LUC **unit IIs3 (650 ha)—**Figures 46, 47

This LUC unit occurs on flat terraces on the south-eastern margins of Lake Rotorua, with thin Rotomahana Mud over older tephras and lacustrine deposits. Its soils are not typical of the subsuite as a whole. Te Ngae loamy sand is a recent soil derived from a mixture of Rotomahana Mud and pumice colluvium and alluvium. Whakarewarewa sandy loam is classified as a composite yellow-brown pumice soil on yellow-brown loam, with irregular cover of Rotomahana Mud, but areas of this soil occurring within the Rotorua Basin were included in the Rotomahana subsuite.

This LUC unit was classified as LUC class II (the only LUC unit away from coastal Bay of Plenty to be so highly ranked) because it has high potential for a wide variety of land uses. Although its soils are prone to drying out they are fertile, and a soil subclass limitation for this LUC unit has been assessed only in the absence of a significant erosion hazard. Although of very limited extent, IIs2 is already diversified and is likely to become more so in the future.

LUC **unit** IIIe3 **(850 ha)—**Figures 46, 47

This LUC unit occurs on undulating to gently rolling slopes mantled with Rotomahana Mud, mainly on terraces in the eastern Rotorua Basin, with small areas in the Rotomahana district. Soils are formed from moderately thick Rotomahana Mud over varying thicknesses of Kaharoa Ash, Taupo Pumice and older tephras.

IIIe3 was distinguished from IIs3 only by its greater slope, which results in a slight to moderate erosion potential under cultivation. However, it has similar pastoral and exotic forestry potentials to IIs3. The main present land use is dairying but there is considerable potential for diversification into arable uses provided erosion control measures such as contour cultivation are undertaken.

LUC **unit IVe3 (1,850 ha)—**Figure 46

This LUC unit has very similar physical characteristics and distribution to IIIe3 but is steeper, occurring on rolling to steeply rolling slopes. Like IIIe3, its principal land use is dairying but stock carrying potential is lower and there are severe limitations to arable use because of a moderate to severe erosion risk under cultivation. However, IVe3 is suitable for occasional supplementary fodder cropping, provided appropriate erosion control measures are undertaken.

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TABLE 19: LUC units on Koiomahana Mud.

LUC UNIT	IIs3	IIIe3	IVe3	VIe7	VIIe3
RELATED LUC UNIT (LUC Suite)					
PHYSIOGRAPHY	Higher lake terraces and alluvial deposits	Hill country		Steep hill country and rhyolite domes	
II Iw I (3) ,	Lake margin I Low lake I terrace and recent lacus- I trine deposits				
		1 850			
				VIIIe3 (8a)	
				|very steep lake scarp	
o	**AREA (ha)**	**PRESENT**	6		850 B B + C	0(2R,G; ISh)
	SLOPES	**EROSION**	5	0		Dairying Orchards
		POTENTIAL	0	0	Rotomahana Rotoiti	
	SOILS	**EROSION**	A	0(0)		C + D C
	% MAP UNITS CONTAINING EROSION	**PRESENT LAND USE**	Te Ngae Whakarewerewa	Dairying Horticulture	0 0	Rotomahana Rotoiti

	1G	10 250		Sheep & cattle Undeveloped Exotic forestry	Okareka Rotomahana	1-2G,sSl; ISh
3	lSh,G(2-3G,R,Sh)	E	54	7 850		3sSl,G,Sh
0		D + E D	lSh,G,T	F E E + F	56	Undeveloped Sheep & cattle Exotic forestry
	Dairying Sheep & cattle Undeveloped	Rotomahana Rotoiti	2G,Sh; IT			

STOCK CARRYING CAPACITY (s.u./ha)	15, 18, 24
SITE INDEX (m)	31-32
	15, 18, 24
	29-32
	14, 16, 20
	29-32
	12, 14, IE
	25-31
	-, 15
	24-31

LUC unit VIe7 (10,250 ha)—Figures 46, 47, 48, 49

This LUC unit comprises strongly rolling to moderately steep hills mantled with Rotomahana Mud, with a potential for moderate gully and sheet erosion. It occurs throughout the subsuite. The same soil series as for IIIe3 and IVe3 have been recorded, but as hill soil phases. Rotomahana Mud is thinner and only recorded in the rock type inventory over about 65% of the area. As a result, the underlying Kaharoa and Taupo ashes are of greater significance and the soils are more erodible and more susceptible to summer drought, as well as having a slight tendency to pug in the winter. Nevertheless, these soils have a higher fertility than neighbouring yellow-brown pumice soils from Kaharoa or Taupo ashes without Rotomahana Mud.

VIe7 has a medium to high potential for both pastoral and exotic forestry use. About 80% of the LUC unit has been developed for these uses. Much of the undeveloped land is low forest which is still regenerating after the Tarawera eruption, especially south of Lake Tarawera; some has been or is being converted to exotic forestry, and most of the remainder is in scenic reserve or has a high biological conservation value.

LUC unit VIIe3 (7,850 ha)—Figures 46, 47, 50

This LUC unit occurs on moderately steep to steep land throughout the subsuite, especially on the higher parts of the ridge separating the Rotorua Basin from the eastern Rotorua lakes. Rotomahana Mud is mapped as a significant rock type over only about 50% of the LUC unit because its depth varies from approximately 5 to 20 cm. Some ignimbrite or rhyolite outcrops occur. Both hill and steepland soils are widely recorded. These are moderately susceptible to drought. VIIe3 has a severe erosion potential; as with VIe7, extensive gully erosion occurred immediately after the Tarawera eruption. Vegetation cover is predominantly woody, much of it regenerating low hardwood vegetation of predominantly scrub species.

VIIe 3 is largely undeveloped, with extensive grazing occurring on about 15% of the area (although present stock carrying capacity was not assessed) and exotic forest on 11%. Pastoral use is not recommended because of a continuing severe erosion potential under pasture. VIIe3 has a medium to high exotic forestry potential but, as with VIe7, much of the area not presently under State Forest tenure is either scenic reserve or would most appropriately be retained with its existing vegetation cover in conjunction with the scenic reserves.

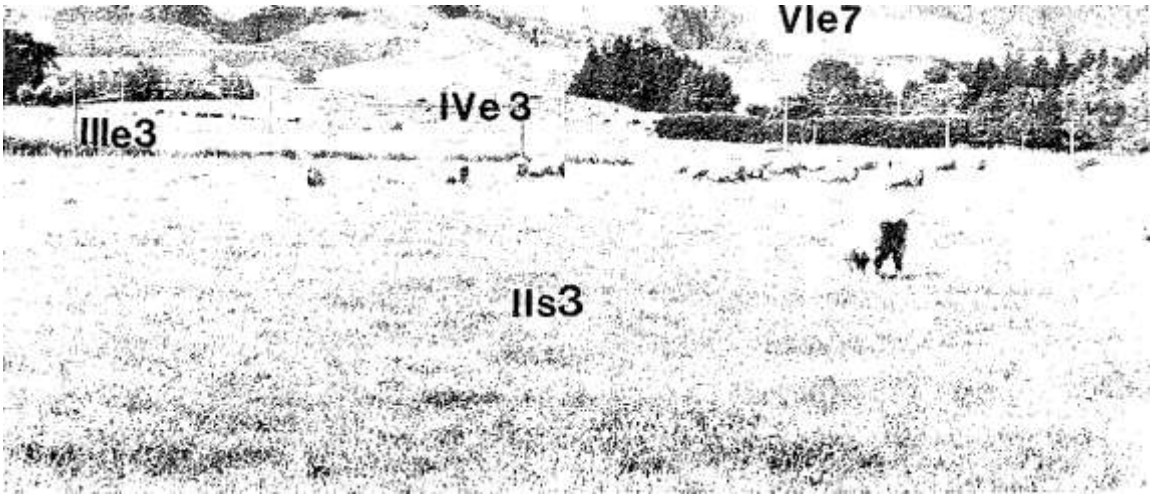

Fig. 46: **LUC subsuite 6b: General view of subsuite in the eastern Rotorua Basin. IIs3 in foreground, IIIe3 and IVe3 on terraces in midground, hills behind are VIe7, and steeper forested slopes in background are VIIe3. Gullies on hillside have been mapped as VIIe9 (LUC subsuite 4b). Eastern Lake Rotorua district, N76/778060 looking SE.**

VIIe3

¥ISe3 ,

■ - lllIIIIIIK^

'.-7:1.1 C suhsuiie 6b: IIs3 in foreground showing horticultural use. Note fine-textured soils. IIIe3 on rolling land, and hills of VIe7 and VIIe3 behind. Eastern Lake Rotorua district, N'76/773040 looking SI-.

f

Fig. 48: **LUC subsuite 6b: VIe7, showing integrated agroforestry land use. Tikitere, N76/795128 looking SE.**

Fig. 49: LUC subsuite 6b: *VIe1,* showing historic rilling processes on Rotomahana Mud, preserved under pasture. Waimungu district, N85/852856 looking E.

Fig. SO: LUC subsuite 6b: VIIe3 occurring close to Mt Tarawera, subject to fluvial and surface erosion on moderately steep slopes. Now largely used for exotic forestry. Waimungu district, N85/832865 looking ENE.

LUC SUBSUITE 6c: NGAURUHOE ASH

General

This subsuite has two definitive characteristics: firstly its mantle of recent Ngauruhoe ash, the only airfall tephra deposit in the region which is presently accumulating, and secondly its elevated position in the north-eastern part of the Volcanic Plateau. Here, a harsh climate, together with the infertile coarse soils derived from the Ngauruhoe ash, result in a generally yery low versatility and high erosion potential. This subsuite is distinguished from the other two in this LUC suite by the andesitic nature of the tephra deposit and by its severe climate. The effects of climate are emphasised by the difference in land use and land use capability between land of similar relief at the lower and upper altitude limits within the subsuite.

The subsuite occurs in the southernmost part of the region, bounded by Mts Ruapehu and Ngauruhoe in the west, Lake Rotoaira and Rangipo in the north, the Kaimanawa Range in the east and the regional boundary in the south (Fig. 42b), across which LUC units in this subsuite are correlated with similar LUC units in the Taranaki-Manawatu Region. On the Tongariro Volcanic Zone volcanoes it was only mapped on the lower slopes; on the steep upper slopes much of the Ngauruhoe ash has been eroded away and the land is more characteristic of general mountain and steepland areas (LUC subsuite 8a). Small areas on Mt Tarawera, which were too small to be separately classified within LUC subsuite 6a, were also included in this subsuite.

The subsuite occupies 23,050 ha, 18% of the area of the LUC suite and 1.3% of the total area of the region. There are four LUC units: IVel6, VIe23, Vllel 5, and VIIIe5, differentiated mainly by altitude. A further LUC unit, VIIIcl, fits partly into this subsuite and partly into LUC subsuite 8a. It has been nominally included in LUC subsuite 8a and described on p. 191: however, those parts that fit better into this subsuite have been shown diagrammatically in Table 20. Around the Tongariro River and the Rotoaira-Rangipo district the subsuite is associated with areas of Taupo flow tephra (LUC subsuites 7f and 7g). Elsewhere it is bounded by areas of general steeplands and mountainlands (LUC subsuite 8a).

Climate

This subsuite is characterised by cold wet weather, the common name 'Rangipo Desert' being in climatic terms a complete misnomer. Rainfall is in excess of 2,000 mm per annum, decreasing from the centre to the north and the south. Temperatures lie between those of Waiouru (mean annual temperature 8.8°C) and Turangi (mean annual temperature 12°C) with ground and air frosts occurring at all times of the year, and some snow in winter. There are no climate stations within the subsuite.

Physiography

In the west and the south the subsuite occurs on the flanks of the andesitic cones of Mts Tongariro, Ngauruhoe and Ruapehu. The main area of the subsuite occurs in the depression between these mountains and the Kaimanawa Range, which has been infilled by lahars from the mountains of the Tongariro Volcanic Centre. These lahars form a ring plain which slopes in a northerly direction down from the regional boundary towards Lake Taupo, and has been extensively dissected and partially infilled with Taupo flow tephra. Lahar surfaces occur also to the west and east of Lake Rotoaira but are partially overlain by Taupo flow tephra and recent alluvium. Almost all of the subsuite is dominantly undulating to rolling, but within these slope groups many dissected areas were recorded. Steep slopes are included in LUC subsuite 8a. The altitudinal range of the ring plain is 580-1075 m a.s.l. but the subsuite rises to nearly 1400 m a.s.l. on the flanks of the mountains.

Rock **Type and Soil Parent Material**

The uppermost rock type, Ngauruhoe ash*, which forms the Ngauruhoe Tephra of Topping (1973), is described as an unweathered, dark, loose andesitic ash, very prone to

***The informal name Ngauruhoe ash has been used throughout this bulletin to retain consistency with the NZLRI rock type classification (Crippen & Eyles 1985).**

erosion. Its texture is variable, including fine to coarse ash, lapilli and blocks. It was recorded in the rock type inventory over more than 80% of the subsuite.

'Mo' ashes are recorded to a depth of approximately 10 m over almost the whole subsuite except for the most recent lahars. These ashes are mainly from the Tongariro Volcanic Centre; they are described by Pullar ***et al.*** (1973) as andesitic Tongariro ashes, but mapped in more detail by Topping (1973) and Topping & Kohn (1973). There are also shallower horizons of several Taupo and Rotorua Sub-group tephras, including Taupo Pumice and Waimihia Lapilli to a depth of 40-60 cm. The local basement rock over most of the subsuite is Rangipo Lahar, a mid-Pleistocene andesitic conglomerate originating from the Tongariro Volcanic Centre mountains (Gregg 1960). This is fringed to the west by various andesitic rocks forming the cones of the volcanic mountains, and to the east by the greywackes and schists of the Kaimanawa Range and by small areas of Waitahanui Breccia, all of which are recorded as minor underlying rock types.

Soils

Most of the subsuite was mapped using soils from the Taupo Survey, with small areas using soils from the General and King Country Surveys. More than 30% of the area is recorded as bare rock or unspecified alpine and subalpine mountain soils with very little profile development. The largest area of classified soils were recent soils from Ngauruhoe Tephra (Ngauruhoe series), which have 30-50 cm Ngauruhoe ash on Taupo Pumice. They are dark, coarse and infertile, very prone to wind erosion and have much rock exposed.

The remainder of the soils, recorded in the north where Ngauruhoe ash is a little thinner, are classified as composite recent soils on yellow-brown pumice soils (Waimarino, Mangetepopo series). Most of the soils reflect the high rainfall environment and are very strongly leached.

Erosion

The subsuite is very extensively affected by surface erosion. Slight erosion was recorded on map units covering 14% of the subsuite, moderate erosion on map units covering 13%, severe erosion on map units covering 13% and extreme erosion on map units covering 20%. Only 34% of the area had no significant erosion recorded. The most important erosion types were wind and sheet, each being recorded on just over 50% of the area. They were commonly both recorded in the same map unit but wind was slightly more significant at severe to extreme severities. Gully erosion was recorded on map units covering 18% of the subsuite. Scree and streambank were minor types recorded, streambank erosion occurring in small areas of redeposited ashes and inclusions of Taupo flow tephra. It is not known if the extreme scree and sheet/wind erosion recorded represents actual present erosion, or merely reflects the amount of bare ground which is maintained by environmental conditions. The subsuite is subject to moderate to extreme potential erosion which is mainly classified under erosion associations E and B.

Land Use and Land Management

Most of this subsuite is undeveloped; only about 5% is in exotic forest and 1% in extensive grazing use, all at lower altitudes (below 800 m a.s.l.) in the northern part of the subsuite. The remaining portion, much of it within Tongariro National Park, is undeveloped. Extensive development of hydro-electric power resources has occurred within the area and involved disturbance of land for dams, lakes, canals and tunnels.

The vegetation of the undeveloped portion shows little change from pre-European times, although it has been affected by fire, and has, of course, been subject to modification by volcanic action. Most of the vegetation is herbaceous, consisting of tussock grassland or subalpine herbfield associations which were recorded on nearly 60% of the subsuite. The main type of tussock grassland is red tussock, with snow tussock also being recorded*.

*The vegetation map of Tongariro National Park (Atkinson 1981), not available at the time of the NZLRI survey, indicates that most of the snow tussock recorded is in fact bristle tussock and danthonia and should have been recorded as short tussock associations. Atkinson's map also indicates that subalpine herb associations were also overmapped in the NZLRI and that some of the tussock-herbfield areas would have been better recorded as tussock-heathland associations with various ***Dracophyllum*** species.

Indigenous scrub, mainly ***Leptospermum*** in the central part of the subsuite, occupies nearly 20%, and a further 10% in conjunction with red tussock. Indigenous forest, mainly beech forest on the margin of the Kaimanawa Range and to the east of Mt Tongariro, occupies 6%. Broom is a common scrub species, often associated with grazing land in the north.

Productive potentials of land in this subsuite are low to medium. Active land use will continue to be centred in the lower altitude northern parts around Lake Rotoaira and Rangipo, where Rotoaira State Forest is expanding, and further small areas may be farmed in conjunction with land on Taupo flow tephra (IVel8, LUC subsuite 7f). Pastoral use is likely to be very minor however, and should only be undertaken with full use of soil conservation measures aimed at minimising bare ground exposure. Compliance with the "Forest Operations" guidelines (NWASCO 1976) is essential for any exotic forestry.

NWASCO (1982) has recommended full use of the subsuite for exotic forestry, apart from areas in the present National Park; however, this recommendation was based on an amalgamation of LUC units in this subsuite with other LUC units which have higher production potentials. It would seem likely that land use patterns over the subsuite as a whole will not change rapidly, with greater emphasis being on development of scenic, recreation and hydro-electricity potential.

LUC Units on Ngauruhoe Ash (Table 20)

LUC unit IVel6 (4,450 ha)—Figures 51, 53

This LUC unit consists of rolling slopes at 600-750 m a.s.l., mantled with thin Ngauruhoe ash. It occurs only in the north of the subsuite, in the Rotoaira-Rangipo district. Compared with the other LUC units in the subsuite, which lie further south, IVel6 is at a lower altitude, with lower rainfall and higher temperatures, is less dissected and has more fertile and better-drained soils with thinner Ngauruhoe ash (Rangipo series, yellow-brown pumice soil). Consequently it has a higher LUC ranking, e.g., a potential for occasional arable use.

IVel6 is the only LUC unit in the subsuite in which significant development has occurred, exotic forest occupying 20% of the area and pastoral land about 5%. Some indigenous logging has occurred on the eastern banks of the Tongariro River, now within the Kaimanawa State Forest Park. These areas are not currently zoned for production. Pastoral capability was not assessed during the NZLRI but is probably 12-14 stock units/ha (medium). Although there is only a slight erosion risk under good pastoral management there is a severe potential under cultivation. Therefore IVel6 is suitable only for occasional root and fodder cropping as part of a pasture rotation. Contour cultivation, provision of windbreaks and the minimising of bare ground are important soil conservation measures. There is potential for expansion of exotic forestry but management should comply with the "Forest Operations" guidelines (NWASCO 1976).

LUC unit VIe23 (2,900 ha)—Figures 51, 52

This LUC unit consists of dissected, undulating to rolling lahar surfaces mantled with Ngauruhoe ash, occurring between 600-900 m a.s.l. in the vicinity of the Desert Road to the oast of Mts Ngauruhoe and Tongariro. Although partially overlapping in altitude with IVel**6,** VIe23 generally lies further south, is more dissected and has a greater thickness of Ngauruhoe ash; these factors restrict its land use capability considerably. It could be equally well classified as having a dominant climate rather than erosion limitation; the LUC unit in the Taranaki-Manawatu Region with which it correlates has in fact been so assessed.

VIe23 has a low potential for both pastoral and exotic forestry use, although about 10% is presently in exotic forest. The remainder is undeveloped, mainly under ***Leptospermum*** scrub. Much of the LUC unit occurs within Tongariro National Park and remaining areas will probably only be developed where they occur in conjunction with IVel6 or other better land.

LUC unit VIIel5 (5,900 ha)—Figures 51, 52

This LUC unit occurs on dissected lahar surfaces mantled by Ngauruhoe ash, lying at 900-1100 m a.s.l. south of the Puketarata Stream. It was also mapped on the top of Mt I arawera. It is distinguished from VIe23 by altitude, and is dominated by herbaceous rather

TABLE 20: LUC units on Ngauruhoe ash.

LUC UNIT	IVe16	Vle23	Vlle15	Vllle5	
RELATED LUC UNIT (LUC Suite)	IVe18 | (7f) !	|VIIIe2| (7f) | t			VIIIcl |VIIIe6 (8a) |(8a)
PHYSIOGRAPHY	Sheet-, Rolling slopes washed' on lahar flow i surface tephra' surface	Dissected slopes 'with flow tephra	on lahar surfaces infill	Lahar surfaces and low of andesitic cone	er flanks *i*
ALTITUDE (m a.s.L)	|600-750	1 1600 -900	900-1100	>1100	>110 0
AREA (ha)	4 450	2 900	5 900	9 750	
SLOPES	C C	C B '	B' C	B' C C'	B' C
SOILS	Rangipo	Ngauruhoe Rangipo	Nguaruhoe	Mountain soils and bare rock Ngauruhoe	Ngauruhoe Mountain soils Makahoe
% MAP UNITS CONTAINING EROSION	0	12	58	100	20
PRESENT EROSION	0	lw	1-3W; 2G; ISh	2-5W,Sh,Sc; 2G	1W,G
POTENTIAL EROSION	lSh(3G,Sh,R)	2-3W	3W,Sh,G	5W,Sh,Sc; 4G	2W,G
PRESENT LAND USE	Undeveloped Exotic forestry Extensive grazing	Undeveloped Exotic forestry	Undeveloped	Undeveloped	Undeveloped
STOCK CARRYING CAPACITY (s.u./ha)	-, -, 11*	-, 5	-. -, o	-, -, 0	

than woody indigenous vegetation. There is therefore much more erosion and bare ground recorded. However, areas of actual erosion are over-represented because of the large size of map units in this LUC unit (see p. 26). Vllel5 is undeveloped for agriculture or forestry. It has a very low physical suitability for both extensive grazing and for production forestry (although trees can be established), and little future development is envisaged. It lies largely within Tongariro National Park.

LUC unit VIIIe5 (9,750 ha)—Figures 51, 52, 54, 104

This LUC unit occurs on undulating to rolling slopes mantled with Ngauruhoe ash at an altitude greater than 1100 m a.s.l., with an extreme erosion potential. It occurs on the flanks of the mountains of the Tongariro Volcanic Centre, as well as on the highest lahar surfaces, as far as the southern boundary of the region. It is not extensively vegetated, and either bare ground or some degree of erosion is recorded over the whole area. Where soil development has taken place, the soils are unspecified subalpine or alpine mountain soils.

Recorded vegetation is mainly red or bristle tussock, subalpine herbs and subshrubs. VIIIe5 is completely undeveloped, lying wholely within Tongariro National Park, and have no potential for development. management should aim at maintenance of indigenous vegetation and the minimising of erosion from recreational use.

Hg. 51: LUC **subsuite 6c: General view showing altitudinal range, with IVel6 on pasture in foreground, VIe23 on manuka scrub and beech forest behind. VIIel5 in centre background and VIIIe5 on mountain slopes. Mt Ngauruhoe in distance. Southern Rotoaira district, Nl 12/267830 looking SW.**

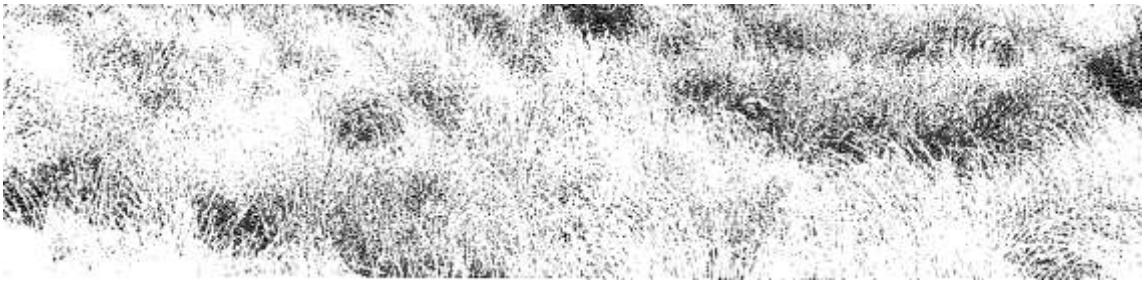

Fig. 52: **LUC subsuite 6c: VIe23 on red tussock and heathland in foreground, Vllel5 behind, VIIIe5 in background. Tongariro National Park, Nl 12/243765 looking W.**

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Fig. 53: **LUC subsuite 6c: IVel6, showing land use at lower altitudinal range of subsuite. Southern Rotoaira district, Nl 12/269832 looking N. Photo: M.J. Page.**

Fig. 54: LUC subsuite 6c: VIIIe5 (foreground) at upper altitudinal range of subsuite, showing bare ground. VIIIe7 on slopes behind and VIIIcl, both LUC subsuite 8a, in right background. Tukino Rd, Tongariro National Park, N122/150670 looking NE. Photo: M.J. Page.

LUC SUITE 7: TAUPO PUMICE

General

The definitive characteristic of this LUC suite is that soils are formed from airfall, flow, or alluvial tephra deposits of the Taupo Pumice Formation (Healy ***et al.*** 1964a). These deposits are derived from the Taupo eruption sequence of 1820 + 80 yr BP, which includes some of the most powerful volcanic eruptions known (Walker 1980). The probable source of this eruption lies close to the Horomatangi Reefs in eastern Lake Taupo (Froggatt 1979; Walker 1981) although additional sources have been suggested (Rijkse 1977). Taupo Pumice as a soil parent material gives rise to yellow-brown pumice soils, whose dominant properties of high friability, coarse texture, acidity, generally low nutrient levels and susceptibility to periods of soil moisture deficiency strongly influence the erosion potential and land use capability of this LUC suite.

The Taupo Pumice LUC suite occupies almost all of the southern half of the region (Fig. 55), comprising the Lake Taupo catchment, the middle Waikato River catchment, the upper Rangitaiki catchment and part of the southern Kaituna catchment. Within these areas it was mapped throughout except on relatively small areas of alluvium (LUC suite 3) or mountainlands and steeplands (LUC suite 8). It is by far the largest LUC suite in the region, and the most complex in terms of the number of subsuites and LUC units. It occupies nearly 800,000 ha or 45% of the total area of the region and has been subdivided into nine subsuites containing 48 LUC units. Taupo Pumice deposits also occur in other NZLRI regions, notably Taranaki-Manawatu and Northern Hawke's Bay. Many of the LUC units in this LUC suite are therefore correlated with LUC units in these two regions.

The division of the LUC suite into subsuites (Table 10) is made on a number of criteria but primarily on the type of Taupo Pumice deposit:

1) On areas of airfall Taupo tephra there are five subsuites (7a-e), which are differentiated on the basis of depth of Taupo tephra, as well as rainfall and general environment (LUC subsuite 7e occurs on mountainlands and steeplands throughout the LUC suite).
2) One large subsuite (7f) covers Taupo flow and water-sorted tephra.
3) Three subsuites deal with mixtures of airfall and flow tephra. The first (7g) is a mapping complex of airfall and flow tephra units too closely intermixed to be separately recorded. The other two occur in special environments where the distinction betwen airfall and flow tephra is overridden by a distinctive climate (7h) or underlying rock type (7i).

It must be emphasised that, although only these last three subsuites are mentioned as being complexes, in fact most if not all of the subsuites include areas of different types of Taupo deposit. This is inevitable when field distinction between the different types of tephra is often difficult. The subsuites themselves are also frequently mapped in complexes; for example, the steepland sub suite (7e) occurs in relatively small areas together with other subsuites either from the Taupo Pumice or other LUC suites.

The number of LUC units in each subsuite ranges from 3 to 11. No LUC class I or II units are recognised, and there are few LUC Class VII or VIII units because most steepland areas were mapped in one of only four LUC units (VIIe6, VIIe7, VIIIe3, VIIIe4; LUC subsuites 7e and 8a). A feature of the LUC suite is the large number of LUC units with a dominant soils limitation (9 out of 48, covering 20% of the area of the LUC suite). This reflects the large extent of flat areas with infertile droughty soils.

Because of the size and complexity of this LUC suite, a brief general description of it is given before the subsuites are separately described. Thus a number of common features in climate, physiography, erosion, land use, etc, are described below rather than be repeated in the descriptions of the subsuites.

Climate

The climate over the LUC suite is varied, but is generally characterised by warm dry summers and cool moist winters. Most of the area has an annual average rainfall of 1150-1500 mm and suffers from soil moisture deficits for more than 40% of the growing season

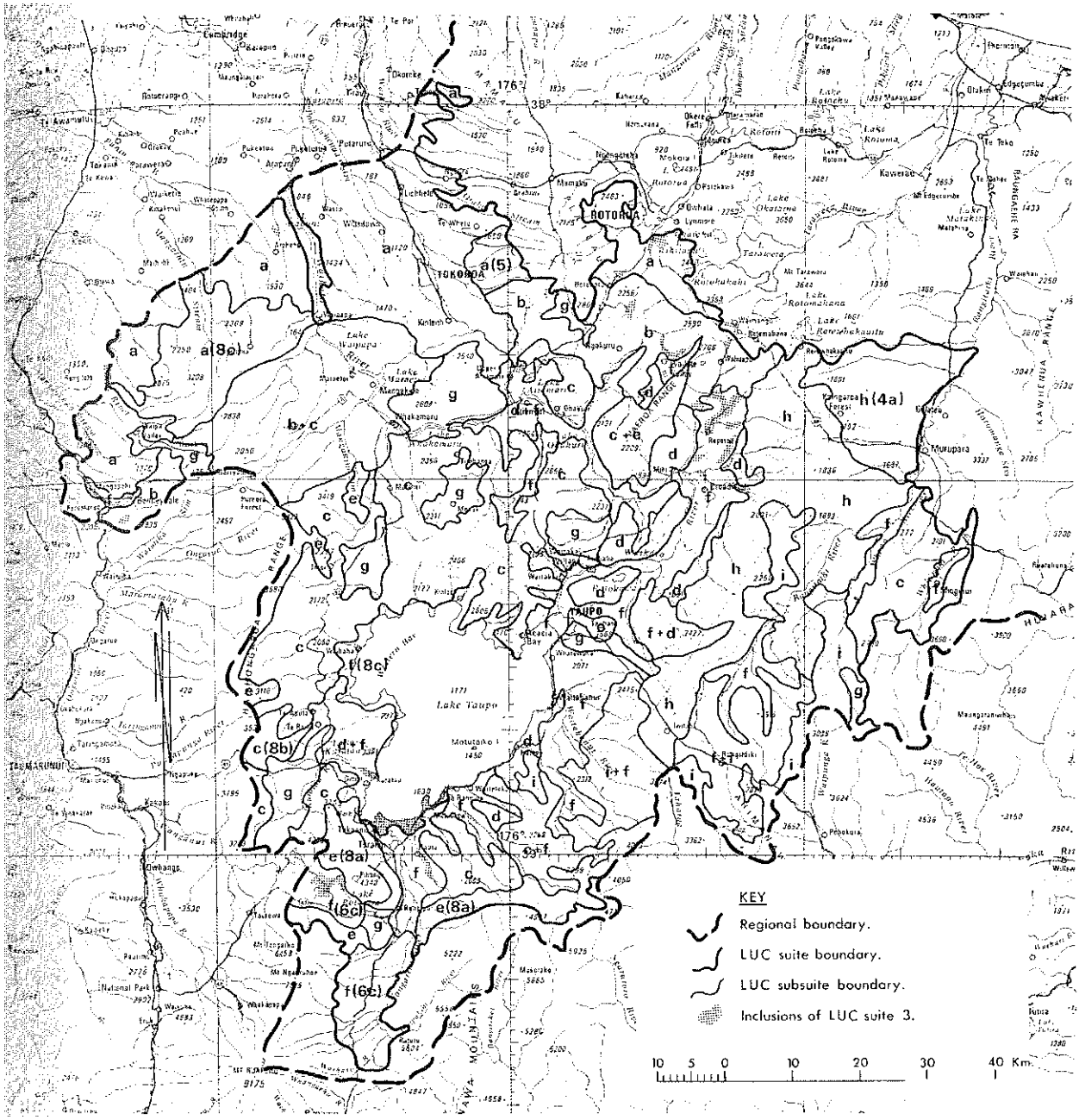


Fig.SS: Distribution of subsuites of LUC suite 7 on Taupo Pumice. Complexes shown by + or (): + indicates complex between two subsuites of LUC suite 7, e.g., b+c = subsuites 7b + 7c; () indicates complex between LUC suite 7 and another LUC suite, e.g., h(4a) = subsuites 7h + 4a. Areas of LUC suite 3 (alluvium) occurring south of the Rotorua district (see Fig. 8) are also shown.

(Fig. 3b). Cool winter temperatures also limit the growing season over much of the LUC suite. Much of the rain occurs as high intensity rainstorms, but by national standards the area is not particularly stormy. A representative climate station, situated roughly in the centre of the LUC suite, is Wairakei Research Station.

The following are the major variations from this representative climate station. In the north (e.g., Rotorua) there is higher and more consistent rainfall. It is slightly warmer, with slightly higher temperature minimums in all months. There are fewer frosts and it is less foggy. In the west (e.g., Tokoroa) the climate is very similar to that at Rotorua except for slightly higher annual rainfall, and more frost days. Around Lake Taupo, temperature regimes are similar but rainfall is rather variable and may fall to below 1000 mm p.a. On the Kaingaroa Plateau, rainfall is slightly higher but more evenly distributed, mean temperatures are lower and, in particular, there are more frosts. All areas at higher altitudes have higher rainfall and colder temperatures, and are subject to occasional snow in winter.

Physiography

The Taupo Pumice LUC suite occurs in all three of the physiographic zones of the Central Volcanic Region described in Chapter 2 (Fig. 2). It ranges in altitude from about 150 m a.s.l. near Putaruru to about 1100 m a.s.l. on the crest of the Hauhungaroa Range. The topography is generally gentle, resulting from the more or less flat ignimbrite sheets which underlie so much of the area, as well as the smoothing and infilling effects of the Taupo cover deposits. The most characteristic topographic system is one of flattish (but often dissected) infilled valleys surrounded by rounded hills. However, many steeper slopes occur, especially at the margins of the LUC suite and near fault scarps.

The LUC suite comprises the following physiographic units which will be referred to in the subsequent subsuite descriptions.

a) **Western Ignimbrite Zone:**

1. The Tokoroa ignimbrite plateau, sloping gently southwards from 150 m a.s.l. at Putaruru to 430 m a.s.l. west of Tokoroa. It is bounded by steep-sided younger ignimbrites and by rhyolite domes to the south.

2. Broken ignimbrite country stretching southwards from Mangakino down the western side of Lake Taupo. This area is dissected by many narrow valleys and has been mantled with tephra in which dry gullies occur. Within it also occur pre-Taupo terrace deposits in a basin around Mangakino, other smallish basins filled with Taupo flow tephra, rhyolitic domes between Mokai and Whakamaru, and the distinctive andesitic cones of Pureora and Titiraupenga.

3. The Rangitoto Range, comprised of dissected ignimbrites rising to 700 m a.s.l., in places deeply eroded and through which underlying greywacke outcrops.

4. The Hauhungaroa Range, which forms the western boundary of the region between the Rangitoto Range and the Tongariro Volcanic Zone. It is an upthrust greywacke block bordered by Miocene sedimentary rocks and lahars.

b) **Taupo Volcanic Zone:**

1. The andesitic cones of Kakaramea and Pihanga, and part of the flanks of Mount Tongariro, occurring in the northern part of the Tongariro Volcanic Centre.

2. Lahar terraces on the northern Rangipo Desert and around Taurewa and Lake Rotoaira, forming part of the Tongariro ring plain. These are overlain by Taupo flow tephra in places.

3. The Taupo Volcanic Centre, comprising Lake Taupo, surrounding cliffs of basalts, rhyolites, pumice breccias etc, and margins infilled with Taupo flow tephra.

4. The Taupo Graben, situated between the Kaingaroa and Whangamata Faults, the Paeroa Range and the Waiotapu district. It is a low lying and flattish area largely filled with dissected breccias, terrace deposits and Taupo flow tephra, but broken by a few rhyolitic intrusions, e.g., Mt Tauhara.

5. The Paeroa Range, a fault block of volcanic rocks rising to 979 m a.s.l. between the Taupo and Ngakuru Grabens. It is bounded to the west by the spectacular Paeroa Fault.

6. The Maroa Volcanic Centre between Whakamaru, Ohakuri and Oruanui, a cluster of rhyolitic domes with a distinctive rounded topography.

7. The Ngakuru Graben, lying between the Paeroa Fault and the Mamaku Plateau, mainly filled with water-deposited pumice breccias and Taupo flow tephra. It is extensively faulted.

8. The south-western part of the Rotorua Caldera and its terrace structures surrounding Lake Rotorua.

c) Eastern Ignimbrite Zone:

1. The Kaingaroa Plateau, a flat-topped ignimbrite plateau at about 550 m a.s.l., ending in steep dissected scarps in many places. It grades into the dissected Matahina Plateau in the north-east.

2. The Rangitaiki Plateau (Upper Rangitaiki Plains), lying to the south-east of and merging into the Kaingaroa Plateau. It is overlain by extensive deposits of deep Taupo flow tephra.

3. Dissected breccia terraces on the eastern side of Lake Taupo, broken by valleys of Taupo flow tephra.

Rock Type and Soil Parent Material

The cover deposit which characterises this LUC suite is the Taupo Pumice Formation. The stratigraphy, lithological variation and modes of deposition of this formation have been discussed in detail by Froggatt (1981). It has been mapped as a significant surficial rock type over nearly 80% of the area of the LUC suite, either as airfall, flow, or water-sorted tephra. On 30% of the area, Taupo Pumice was the only rock type recorded; this was almost always deep Taupo flow tephra. As well as water-sorted tephra (both alluvial and lacustrine), tephra re-deposited as colluvium (Rijkse 1977) is significant. The distinction between any of these forms in the field is often difficult to make, especially close to source. In many cases more than one type of Taupo tephra will have been mapped together*.

On 20% of this LUC suite, Taupo Pumice was not thick enough to be recorded as a significant rock type, because of steep slopes from which tephras were rapidly eroded, but it was still the most important soil parent material. More recent ashes (Kaharoa, Tarawera, Rotomahana and Ngauruhoe ashes) overlying Taupo Pumice were significant as a soil parent material in some areas but were rarely mapped as a rock type.

Pre-Taupo tephra deposits, both 'Mo' ashes and lapilli, were recorded over almost all of the LUC suite except for areas of deep flow tephra. Lapilli is of particular significance because of its importance in the erosion pattern; one subsuite and several LUC units within other subsuites have been defined by the presence of various lapilli formations. The various tephras covering the LUC suite have been described and mapped by several authors. (See Chapter 3. Significant references for this LUC suite include Healy ***et al.*** (1964a), Pullar ***et al.*** (1973), Topping & Kohn (1973), Vucetich & Howorth (1976b), Walker (1981).)

Because of the deep tephra cover, local basement rocks were only recorded in the inventory over about 60% of the area. 'Hard' volcanic rocks such as ignimbrites and rhyolites were most common, followed by older breccias such as the Waitahanui and Earthquake Flat Breccias. Greywacke, unconsolidated Pleistocene sediments, and older sedimentary rocks were recorded in small areas.

-oils

Just under 50% of the LUC suite was mapped using soils from the Taupo Survey. Soils from the General, King Country and Waiotapu Surveys were each recorded on between 10 and 20% of the LUC suite, while soils from the Northern Kaingaroa, Rotorua and Whakatane Surveys were recorded over small areas.

* According to current thinking the term 'airfall' is a misnomer because the Upper Taupo Pumice Member of Healy ***et al.*** (1964a), which is widespread in areas mapped in airfall Taupo subsuites, is primarily a tephra flow deposit (Froggatt 1981). The term is retained to refer to Taupo deposits which are primarily shower bedded, notably Members 3 and 6 of Healy's Taupo Pumice Formation (further described by Walker 1980, 1981).

TABLE 21: **Soil groups in the Taupo LUC suite.**

Soil group	*% of LUC suite*
Yellow-brown pumice soils	**62**
Related podzolised soils	**22**
Related steepland soils	**7**
Composite yellow-brown pumice soils on yellow-brown loams	
Yellow-brown loams	
Composite recent soils on yellow-brown pumice soils . .	
Recent soils from volcanic ash	
Recent soils from alluvium	
Organic soils	

Table 21 shows the soil groups recorded within the LUC suite. (In this table some soil groups have been combined.) By far the most extensive soil group is yellow-brown pumice soils from Taupo Pumice. (Soils derived from both airfall and flow tephra are classified as yellow-brown pumice soils.) The next most extensive soil group is podzolised yellow-brown pumice soils, occurring in high rainfall environments. Significant areas of yellow-brown loams or composite yellow-brown pumice soils on yellow-brown loams occur at the edges of the LUC suite where Taupo Pumice is thinner. The total area for podzolised soils also includes podzolised yellow-brown loams and composite soils. Steepland soils also occupy a significant area. Smaller areas are occupied by composite recent soils on yellow-brown pumice soils or recent soils from volcanic ash (where Taupo Pumice is overlain by recent ashes), and recent soils from alluvium or organic soils, where there is present accumulation of redeposited ashes occurring. These soil groups are further discussed in the individual subsuites.

Erosion

Erosion is recorded on map units covering 33% of the LUC suite. The most common type is sheet erosion, which affects map units covering 20% of the area (60% of the area on which erosion was recorded). Gully erosion is the next most important erosion type, affecting map units covering 13% of the LUC suite. Soil slip and streambank erosion each affect map units covering about 4%, with streambank being slightly more prevalent at moderate erosion severity. Minor erosion types recorded include rill, tunnel, debris avalanche and deposition. This latter phenomenon, included as an erosion form for convenience, has been under-recorded because, although erosion of the thick tephras in the Taupo region releases large amounts of material into stream channels, when it is redeposited downstream it is usually included with previously redeposited material as water-sorted tephra.

The comparative importance of gully and sheet erosion is difficult to judge precisely because it is not possible to directly compare the severity of surface and fluvial erosion types from NZLRI records. It is only possible to say that gully erosion was comparatively more often recorded at moderate or greater severity than sheet erosion and that its immediate impact on land use and communications has probably been more significant. However, the area exposed to sheet erosion is certainly more extensive, and is probably more important as a source of soil loss in the long term. Erosion type is related to physiography, with sheet occurring on exposed land surfaces, especially on hillslopes, and gully occurring mainly in valley floors and terraces. This also corresponds to a soil parent material difference in that gullies occur mainly in flow tephra or colluvial deposits while sheet is generally more prevalent on airfall deposits. Stock movement is thought to be a significant factor in the initiation of sheet erosion. Streambank erosion also occurs mainly on flow tephra and is often recorded together with gully erosion. Soil slip is not significant where Taupo Pumice is thick but is much-more common in steeper areas on the periphery of the LUC suite.

Although the physiographic and lithological control of erosion in Taupo Pumice is still poorly understood, a number of studies have been made of the erodibility of soils derived from Taupo Pumice. These have been summarised by Selby (1972) and Selby & Hosking (1973). The latter authors conclude that increased runoff under pasture, particularly on soils with a low moisture content which have been compacted during conversion from native

forest, is very important in the initiation of gully erosion. Blong (1966) and Healy (1967) investigated the morphology of gully erosion and drew attention to the presence of numerous discontinuous gullies and dry valleys (ephemeral waterways), probably associated with erosion shortly after the Taupo eruption.

Land Use and Land Management

The most extensive present land use is exotic forestry, which occupies nearly 40% of the arc;i. Pastoral uses, predominantly sheep and cattle raising, occupy about 30% of the area. Dairying is a significant but declining land use on the better land in the north, while deer farming and to a smaller extent goat farming are minor but increasing land uses in higher rainfall areas. Arable use is minor in most districts and is mainly confined to supplementary fodder cropping. Improved and unimproved pasture occur in approximately equal proportions. About one third of the pastoral area is extensive pastoral land with a mixed grassland and indigenous scrub cover. Gorse, broom and blackberry are the main exotic scrubweeds but are comparatively rarely recorded at the scale of mapping.

The rest of the LUC suite (about 30%) is undeveloped. Most of this land is indigenous forest and scrub, on which a small amount of milling takes place. About 8% of the LUC suite is unlogged indigenous forest. Half of this is podocarp-hardwood forest, which is concentrated in the West Taupo-Rangitoto Range area and in Whirinaki State Forest. The other main type is beech forest on the western Kaimanawa Range. Minor podocarp forest and hardwood forest occur, but hardwood forest is most commonly mapped with indigenous scrub where logging has taken place. Indigenous scrub associations (often dominated by manuka) occur on about 5% of the area. Some of these are successional while others occur in cold or infertile environments such as frost flats, where forest establishment is very slow. Natural heath land vegetation (Burrows ***et al.*** 1979), which formerly covered much of the Kaingaroa Plateau and Rangitaiki Valley, is now insignificant in the vegetation as a whole but is mapped in association with grassland over about 2% of the area. Most of this is mixed short tussock and heathland association on the Upper Rangitaiki Plains. Wetland associations are commonly mapped as minor elements within pasture, as well as in occasional undeveloped swamps.

The major trend in land use is an increase in exotic forestry, at the expense of both undeveloped and extensive pastoral land. This trend is supported by NWASCO (1982) which recommends a dominantly exotic forest use on the non-arable land. However, much of the undeveloped land with indigenous forest cover is State Forest with both protection and production functions, so that substantial areas of indigenous forest and scrub are likely to remain. Most land in the LUC suite has a medium to very high exotic forestry potential while pastoral potential is more variable. In the medium term, total pastoral production is unlikely to decline in the face of forestry expansion, because it is capable of considerable intensification, as well as some further development. However, arable use is not expected to expand significantly.

The main limiting factor over the LUC suite as a whole is probably summer soil moisture deficits. These not only have a negative influence on pastoral production, but also increase the susceptibility of pastoral areas to erosion and to infestation by pests such as grass grub. The growing of lucerne is becoming increasingly important in pastoral management because its deep-rooting habit enables it to withstand soil moisture deficits better than most grasses. l-.';otic forest plantations are also less susceptible to moisture stress. The main requirement in any form of land management, however, is sensitivity to the unconsolidated nature of the upper soil horizons, whether flow or air fall tephra derived. This applies to diverse operations such as roading construction, load haulage, placement of fences, stock movements, etc.

LUC SUBSUITE 7a: SHALLOW TAUPO PUMICE

General

This subsuite is characterised by the presence of shallow Taupo Pumice, generally giving rise to composite yellow-brown pumice soils on yellow-brown loams. It occurs on the northern and western margins of the Taupo LUC suite and is intermediate in character between areas to the north-west (Waikato NZLRI Region) without significant Taupo Pumice (yellow-brown loams), and areas to the south-east and south (LUC subsuites 7b and 7c) with deeper Taupo Pumice (yellow-brown pumice soils). The subsuite is thus comparable to LUC subsuite 4a on shallow Kaharoa Ash but is distinguished from it chiefly by climate. Because of a temperate climate without extremes, generally moderate relief and versatile soils, LUC units in this subsuite have been given the highest LUC rankings in the Taupo LUC suite.

The main part of the subsuite occurs in an arc stretching from Mangapehi (King Country) to Rotorua (Fig. 55). This area has a south-east extension between Kinleith and Atiamuri, and a narrow northward extension to the west of the Mamaku Plateau. Within the area occur the northern Rangitoto Range (LUC subsuite 8c) to the west, and the Mamaku Plateau (LUC suites 8 and 5) in the north.

The subsuite contains five LUC units: IIIsl, IIIe4, IVe4, VIsl and VIe5. Several of these are widespread, and the subsuite is one of the largest in the region; its area is 142,400 ha, 18% of the Taupo LUC suite and 8.0% of the total area of the region. The LUC units are differentiated mainly on the basis of slope. VIsl and VIe5 are particularly widespread because they have no direct equivalents in the adjacent subsuite on thicker Taupo Pumice (LUC subsuite 7b) and were therefore extended into that subsuite. Areas of LUC Class VII or VIII occurring within the subsuite were included in LUC subsuite 4a in the Rotorua district (see p. 69), or LUC suite 8 elsewhere. Small areas of Taupo flow tephra were included in LUC subsuite 7f. The subsuite grades into LUC subsuites 7b and 7c to the south-east as Taupo Pumice thickens.

Climate

The climate over most of the subsuite is generally moist and mild, although winters are cool. Annual rainfall over most of the subsuite is 1400-1600 mm, but increases to more than 2000 mm in the Rangitoto Range. The representative climate stations are Tokoroa and Rotorua.

Physiography

The subsuite occurs mainly on the Tokoroa ignimbrite plateau and the western ignimbrite country, with smaller areas occurring in the Rangitoto Range, the Rotorua Caldera and the northern Ngakuru Graben. Generally, the landscape is of low relief, predominantly undulating to gently rolling on the Tokoroa Plateau, becoming more broken west of the Waikato River and much steeper in the Rangitoto Ranges and to the south-west. Most steep slopes are included in VIIe4 (LUC subsuite 8c). The country south of Rotorua is fairly broken, reflecting complex structural geology. The five LUC units together form a continuum of slope from flat to moderately steep.

Rock Type and Soil Parent Material

The subsuite is mantled by Taupo Pumice whose depth is variable but generally between 20-40 cm. It was only occasionally recorded in the rock type inventory. Taupo Pumice is mainly an airfall deposit in this subsuite, although small areas of shallow water-sorted tephra near Tokoroa were included, and much of the Taupo Pumice on the flat to easy rolling country of the Tokoroa Plateau has been redeposited by sheet wash.

Underlying the Taupo Pumice is approximately 5 m of 'Mo' tephras including tephric loess in places. These tephras thicken to the south and thin out to the west. The local basement rock over 75% of the subsuite is ignimbrite (Whakamaru, Marshall and Pakaumanu Formations). Greywacke outcrops in the Rangitoto Range and is mapped as the underlying rock type over about 10% of the subsuite, while the remainder is underlain by various volcanically derived sediments and breccias (mapped as Us or Ft) south of Rotorua. The

underlying rocks over most of the subsuite are stable, although the breccias, sediments and some of the top zones of the ignimbrites are not welded.

Soils

About 65% of the subsuite was mapped using soils from the General Survey, 20% using soils from the King Country Survey, and remaining areas using soils from the Rotorua and Waiotapu Surveys. Overall, only 48% of the subsuite had soils classified as composite yellow-brown pumice soils on yellow-brown loams, compared with 45% classified as yellow-brown pumice soils. This seemingly contradicts the definition of the subsuite as discussed above. However, most of the areas where yellow-brown pumice soils were recorded, principally in the Tokoroa district, were mapped using soils from the General Survey. Field examination indicated that many of these soils (mapped as Taupo set) would now be classified as composite soils. Although Taupo Pumice thickens south of Tokoroa, it is considered that composite soils occur as far south as the Kinleith area. Only small areas of the yellow-brown pumice soils are shown as being derived from water-sorted tephra (Tokoroa set) but this is an underestimate.

Small areas, mainly in the Rotorua-northern Waiotapu district, have soils classified as yellow-brown loams (Ngakuru series). These were separated from yellow-brown loams in the Tauranga district (LUC suite 1) and included with this subsuite because of the overriding importance of climate. Most of these yellow-brown loams are hill soils; rolling phases of the same soils have thicker Taupo Pumice and would be classified as composite soils. However, areas in the Rotorua Basin with yellow-brown loams, mapped in the NZLRI in Ll'C subsuites 4a and 7a, are very similar in land use capability*.

Many of the soils are moderately to strongly leached, about 20% of the subsuite, in areas around the Rangitoto Range and Mount Ngongotaha, having podzolised soils (Owawhango, Ngaroma and Ngongotaha series) recorded.

Erosion

Oi' all the Taupo subsuites, this is the least affected by erosion. Slight erosion was recorded on map units covering 25% of the subsuite and moderate erosion on map units covering 3%. Sheet is by far the major type, affecting 85% of the area where erosion was recorded. Gully and soil slip erosion were the other two most common types; soil slip was more commonly recorded, but gully erosion is probably more severe in terms of difficulty of repair. Soil slip occurs only on steeper areas with a thin cover of Taupo Pumice (mainly VIe5) and is initiated in the 'Mo' ashes beneath the Taupo Pumice. Minor erosion forms recorded wei\.: streambank, earth slip and tunnel gully. Gully and streambank erosion are particularly associated with redeposited tephras occurring near watercourses in the Rotorua district. Potential erosion is assessed as slight to moderate under pastoral use, and the erosion association is classified as associations P and R.

La::.-" Use and Land Management

About 50% of the subsuite is used for grazing. This area is divided equally between dairying, centred around Tokoroa and Rotorua, and sheep and cattle fattening, occurring south of Rotorua, west of the Waikato River and in the King Country. Dairying is heavily dependent on the use of winter fodder crops. Exotic forest occupies 30% of the subsuite, while the remainder is undeveloped. Undeveloped land is divided between indigenous forest, forest-scrub mixtures, and pockets of scrub and remnant hardwood forest occurring within pastoral land. Gorse is the main exotic scrubweed. Both vegetation and land use show a rather marked contrast between the eastern and western sides of the subsuite. To the east of Wharepuhunga the vegetation is dominated by improved pasture and exotic forest, whereas to the west it is dominated by indigenous forest, scrub and rough pasture-scrub mixtures.

***The recent Otorohanga Survey has mapped a small area of the Bay of Plenty-Volcanic Plateau Region in the south-east corner of NZMS1 N74. Soils in this area have been classified as yellow-brown loams (Maihihi series), divause these are hill soils, there may be a sufficient thickness of Taupo Pumice on rolling land to recognise composite soils as well. However, this survey indicates that more extensive re-mapping may result in a small shift of the boundary between composite yellow-brown pumice soils and yellow-brown loams, and hence the Bay of Plenty-Volcanic Plateau/Waikato regional boundary, in the area between the Waikato and Waipa Rivers.**

The land use pattern is fairly stable and could be expected to stay so. On arable land, there is potential for intensification of pastoral use because the arable LUC units have a moderate to high potential for both sheep and beef grazing and for dairying, and there is also some potential for diversification on the best land. Undeveloped land would be expected to be developed for exotic forestry or grazing use, although areas in the northern Rangitoto Range will be managed primarily for water and soil conservation because the headwaters for several major catchments lie in this area.

LUC Units on Shallow Taupo Pumice (Table 22)

LUC **unit IIIsl (1,350 ha)—**Figure 57

This LUC unit occurs on flat and undulating surfaces on shallow Taupo Pumice that have no significant erosion risk. It is located around Tokoroa and Kinleith. Although most of the soils (Tokoroa sandy silt and sand) are probably derived from water-sorted Taupo tephra, IIIsl also occurs on areas of airfall tephra. It has the highest present stock carrying capacity in the subsuite, but does not have quite so high a potential stock carrying capacity as IIIe4 or IVe4, possibly because of slightly impeded drainage or colder microclimates. Present land use is almost exclusively pastoral but some orcharding occurs near Tokoroa and there would be scope for further horticultural production with the provision of shelter.

LUC **unit** IIIe4 **(12,800 ha)—**Figures 56, 57, 58

This LUC unit occurs on undulating to rolling slopes on shallow Taupo Pumice. It is scattered throughout the subsuite although centred in the Tokoroa district. Like IIIsl, IIIe4 occurs on water-sorted as well as airfall Taupo Pumice (but both were mapped as Taupo set in the General Survey). It has a high and very high potential for pastoral and exotic forestry use respectively and is capable of considerably diversified and intensified land use. Although there is a moderate erosion risk under arable use, this can be reduced by contour cultivation and the provision of shelter.

LUC **unit IVe4 (34,300 ha)—**Figures 56, 58, 59

This LUC unit occurs on rolling slopes on shallow airfall Taupo Pumice. It has a very similar distribution to IIIe4 and has similar recorded inventory factors except for a steeper slope which results in a greater erosion risk under cultivation. IVe4 is marginal for arable use but winter fodder cropping is common in rotation with pasture. From the point of view of land use and potential, IVe4 is also very similar to IIIe4, except that it is more extensively used for exotic forestry (about 30% of its area) and has a wider variety of existing vegetation cover. Agricultural use requires a greater intensity of soil conservation practices than on IIIe4.

LUC **unit VIsl (24,150 ha)—**Figures 56, 57

This LUC unit occurs on strongly rolling to moderately steep slopes on shallow airfall Taupo Pumice which have no significant erosion hazard under non-arable use. VIsl continues the slope continuum from IVe4 and north of Tokoroa the two LUC units are mapped as complexes. Large areas also occur in the southern part of the subsuite on the old ignimbrite surfaces surrounding the Rangitoto Range. It is not mapped in the Rotorua area. Because VIsl is common in areas which receive higher rainfall, more than 30% of its area has podzolised soils, a much higher proportion than on other LUC units in the subsuite. Although, under good management for non-arable use erosion is not judged to be the dominant limitation, VIsl is still subject to minor sheet and occasional soil slip erosion.

Dairying is a minor land use, and pastoral potential is not as high as on arable LUC units. NWASCO (1982) recommends that most of the presently undeveloped land be developed for exotic forestry, for which it has a high to very high potential.

LUC unit **VIe5 (69,750 ha)—**Figures 56, 57, 59, 60

This LUC unit occurs on moderately steep hills with a mantle of shallow to moderately deep airfall Taupo Pumice. It was mapped throughout the subsuite and also extends to the south as far as the Waikato River between Upper Atiamuri and Waipapa, i.e., within LUC

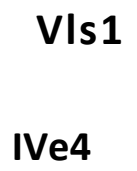
TABLE 22: **LUC units on shallow Taupo Pumice.**

LUC UNIT	IIIsl	IIIe4	IVe4	VIsl	VIe5
RELATED LUC UNIT (LUC Suite)	IVel31 (7g) |	VIIel, VIIe4			
PHYSIOGRAPHY	VIel 7 '(7b)	Rolling - strongly rolling plateau surfaces (dissections infilled with Taupo flow tephra)		Hill country	Steep hill country, ranges and scarps
	Flat plateau surface				
		12 800 (4a) (8c)			
AREA (ha)	A + A				E + F E + D
SLOPES		Taupo Ngaroma Owawhango	Taupo Ngaroma	Ngaroma Taupo Owawhango	Taupo Ngaroma Ngongotaha Ngakuru
	Tokoroa				
SOILS		12	11	20	51
		lSh,G,Sb	lSh,G,Sb	lSh,sSl	1-2Sh; lsSl,G
	0	0(2Sh,W,R; 1G)	0-lSh (2-3Sh,W,R; 2G)	lSh,sSl	2Sh,sSl; 1G
% MAP UNITS CONTAINING EROSION	0				
PRESENT EROSION	0(0)	Dairying Sheep & cattle Exotic forestry	Dairying Exotic forestry Sheep & cattle Undeveloped	Sheep & cattle Exotic forestry Undeveloped Dairying	Exotic forestry Sheep & cattle Undeveloped Dairying
POTENTIAL EROSION		34 300	24 150	69 750	
PRESENT LAND USE 1 350	Dairying Sheep & cattle	C	D	E	
	B + C B	C + D	D + E		
STOCK CARRYING CAPACITY (s.u./ha)	19, 22, 23	18, 20, 25	32-37		
SITE INDEX (m)	33-35	30-37	15*, 17*,		
	18, 20, 25	16*, 18*,	18*		
	34-37	20*	28-37		

subsuite 7b on moderately deep Taupo Pumice, where no comparable LUC unit was recognised. VIe5 is therefore the most extensive and variable LUC unit in the subsuite and one of the most extensive hill country LUC units in the region. However, in detailed remapping it would probably be subdivided. It occurs mainly on stable rock types but, because no LUC unit was distinguished on unstable rock types within this subsuite, it was also recorded on various unwelded pumice breccias and deposits, mainly in the southern Rotorua district.

Because of the wide distribution of VIe5, and the resulting variation in thickness of Taupo Pumice, a variety of soils are present. However, nearly 80% of the area is mapped with Taupo or Ngaroma soils. Sheet is by far the dominant erosion form. Gully and tunnel gully erosion occur in areas where VIe5 was mapped on unwelded rock types, e.g., Earthquake Flat Breccia.

Present land use is fairly evenly divided between exotic forestry, sheep and cattle fattening, and extensive grazing. Both stock carrying capacity and exotic forest growth potential is somewhat variable. Pastoral potential depends on aspect and may be subject to depression from grass grub infestation, especially on steeper faces. Such slopes would be most suitable for exotic forestry, subject to the "Forest Operations" guidelines (NWASCO 1976). However, less steep slopes are suitable for intensive pastoral use. Recommended soil conservation practices include minimisation of bare ground by good grazing management, gully control, and open planting of potential slip faces.



VIel

Fig. 56: **LUC subsuite 7a: General view over subsuite. IIIe4 and IVe4 in foreground, VIe5 and VIsl on hills behind. Lichfield district, N75/300100 looking NE.**

'/: i .1 C **subsuite 7a: IIIe4 on gently rolling slopes in foreground (airfall tephra) and IIIsl in valley flats in middle of photo (water-sorted tephra). VIsl and VIe5 on hills behind. Matarawa Rd, Kinleith district, N84/418882 looking SW.**

LLC subsuite 7a: IVe4 (background) and IIIe4 (foreground) on rolling land. Lichfield district, N75/294083 looking SW.

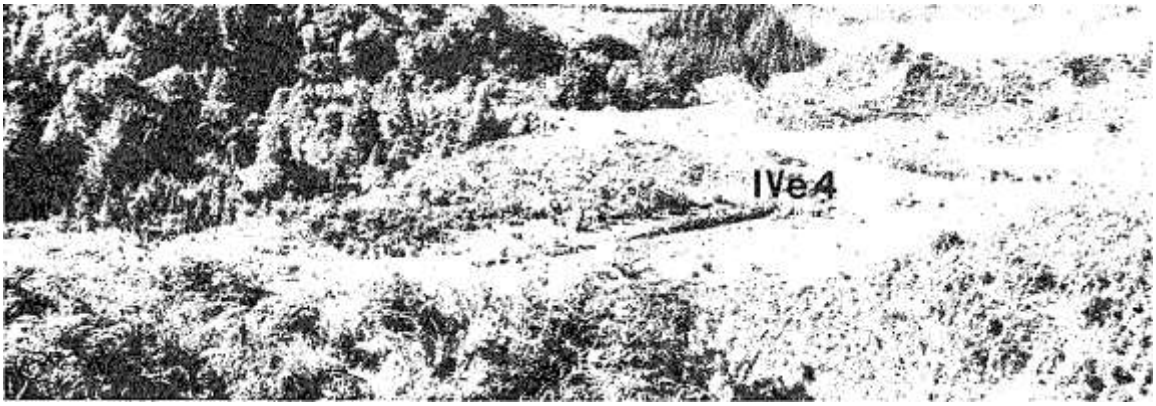


Fig. 59: **LUC subsuite 7a: Relationship between VIe5 on hills in background and midground, and VIIe4 (LUC subsuite 8c) on ignimbrite scarp at left. IVe4 on rolling ground in valley. Southern Rotorua district, N76/654974 looking NE.**

LUC SUBSUITE 7b: MODERATELY DEEP FINE TAUPO PUMICE

General

This subsuite has three distinguishing characteristics. Its soils are formed on moderately deep airfall Taupo Pumice, whose depth is somewhat variable but generally 40-60 cm. More importantly, it tends to be much finer than Taupo Pumice occurring closer to source (LUC subsuites 7c and 7d), resulting in more finely textured soils. Finally, the subsuite has a slightly moister and cooler climate compared with areas of deeper and coarser Taupo Pumice. This, combined with the finer textured soils, results in a more favourable environment for pasture growth.

The subsuite occurs in two main areas (Fig. 55): firstly, the district between Whakamaru and the southern Rangitoto Range; and secondly, the Ngakuru-Horohoro-Waiotapu district in the northern Ngakuru Graben. Smaller areas also have been mapped in the Benneydale district and to the west and north of Lake Taupo. In general it occurs in between LUC subsuite 7a on shallow Taupo Pumice and LUC subsuite 7c on deep Taupo Pumice. It is mapped together with LUC units from both these LUC subsuites as well as from LUC subsuite 7f (Taupo flow tephra).

There are five LUC units in the subsuite, differentiated by relief. IIIs2 occurs on flat land, IIIe6 and IVe6 on rolling land, IVell in distinctively dissected areas and Vie 17 on steeper hill country on unstable underlying rock types. Areas of LUC class VII and VIII occurring within the subsuite were included in LUC subsuites 4a (see p. 64) or 8c. In the western portion of the subsuite, arable LUC units from this subsuite have been widely mapped together with non-arable units from LUC subsuite 7c (see p. 135). The separation of these two subsuites on the basis of soil texture has not been entirely consistent, especially the separation between LUC units IVe6 (this subsuite) and IVe8 (LUC subsuite 7c), which were both mapped with VIe9 (LUC subsuite 7c) west of Mangakino. The area of the subsuite is 40,400 ha, 5% of the Taupo LUC suite and 2.3% of the total area of the region.

Climate

The climate in the western area of the subsuite is distinctly wetter and cooler than the 'typical' climate over the Taupo LUC suite. The representative climate station is at Pureora Forest, just to the south-west of the subsuite. The eastern area is also slightly cooler and has a slightly less dry summer than the 'typical' Taupo climate. The representative climate station for this area is at Waiotapu. The Ngakuru-Waikite area is well known for persistent winter fogs.

Physiography

The western area occurs in the Mangakino-Western Taupo ignimbrite country, between about 240 m a.s.l. along the Waikato River and 600 m a.s.l., with associated rhyolite domes and alluvial fans around Mangakino. The eastern area occurs in the Ngakuru Graben at 350-450 m a.s.l. The subsuite is generally one of very gentle relief with little steep country (although some hill country and steepland areas are mapped in other LUC suites). However, there are many dissected slopes.

Rock Type and Soil Parent Material

Taupo Pumice that was deep enough to be recorded as a rock type occurs on over 80% of the subsuite, although some of this is only significant in patches. The areas where it was too thin to be recorded as a rock type are on hill country in the north of the subsuite. A characteristic of the subsuite, especially in the eastern area, is that much of the ash cover has been redeposited by colluvial or alluvial processes. This has resulted in uneven thickness of surface tephra layers, while sorting during redeposition has been a factor in the fine texture of the Taupo Pumice. Small areas of Taupo flow tephra also occur within the subsuite, but these are mainly included in LUC subsuite 7f. A variety of 'Mo' deposits underlie the Taupo Pumice, with undifferentiated brown tuffs, Oruanui Ash and tephric loess prominent in the western area and an extensive sequence of Rotorua Sub-group tephras in the east.

Whakamaru and Pakaumanu Ignimbrites underlie most of the western area of the subsuite, but were not included in the rock type inventory over large areas of gentle relief, where only the tephra cover was recorded. The main recorded basal rock type was Us, consisting mainly of interbedded pumice breccias and sandstones of the Huka Formation in the Ngakuru Graben, as well as more recent sandy terrace and fan deposits. Earthquake Flat Breccia (recorded as Ft) was the underlying rock type on small areas.

Soils

Almost 50% of the area of this subsuite was mapped using soils from the Waiotapu Survey, and 20% using soils from the the Taupo Survey, while smaller areas are covered by the General, King Country and Rotorua Surveys.

Yellow-brown pumice soils are mapped over 80% of the subsuite. The preponderance of loamy soils, e.g., Taupo and Oruanui sandy silts (sandy loams), reflects the fine texture of Taupo Pumice in the subsuite. Most of the other soils recorded are composite yellow-brown pumice soils on yellow-brown loams (Ngaroma series) or yellow-brown loams (Ngakuru series) occurring near the northern and western boundaries of the subsuite. The Ngakuru series is marginal between a yellow-brown loam and a composite yellow-brown pumice soil on yellow-brown loam. Many of the soils in the western area are moderately to strongly leached, with podzolised soils (Tihoi and Ngongotaha series) being recorded on about 15% of the subsuite. No steepland soils are recorded, as steepland areas are included in other LUC subsuites (7e, 8c).

Erosion

Slight erosion was recorded on map units covering 25% of the subsuite, and moderate erosion on map units covering 4%. The low incidence of recorded erosion reflects the gentle relief of this subsuite. The most common erosion type is sheet, which is recorded on map units covering 18% of the subsuite (62% of the area on which erosion was recorded).

Compared with LUC subsuite 7a, soil slip erosion was comparatively minor in occurrence. However, gully or rill erosion was recorded on 13% of the map units, and streambank on a further 8%. Gully erosion was the most common erosion recorded at moderate severity. Potential erosion has been assessed as moderate to severe, and the erosion association classified as mainly association P with some association R on arable land.

Gully erosion in the Whakamaru district and in the Mangakowhiriwhiri catchment in particular, has been studied in some detail (Healy 1967; Blong 1966; Selby & Hosking 1973) and its possible mechanisms discussed.

Land Use and Land Management

The present land use pattern is rather similar to that on LUC subsuite 7a. Sheep and cattle grazing occupies almost 40% of the area, mainly on steeper land, while dairying occupies about 20%, mainly in the Ngakuru-Horohoro district. Exotic forestry occupies about 30% of the subsuite. Only about 10% is undeveloped at present. Much of this latter portion is podocarp-hardwood forest and indigenous scrub in the southern Rangitoto Ranges, on which minor indigenous logging occurs. There is little undeveloped land in the eastern area except for minor patches of exotic scrubweeds in grazing areas, and swampy areas (containing swamp vegetation usually dominated by flax) in valley floors and depressions.

The major trends in land use recommended by NWASCO (1982) are shifts from grazing to dairying on arable land, and to exotic forestry and sheep and more intensive cattle grazing on non-arable land. The proportion of exotic forest is unlikely to increase overall by more than about 5% even though some steeper areas are more suited to exotic forestry than to pastoral use. The recommended shift to dairying will depend largely on economic factors. At present there is virtually no horticultural or intensive arable use, but both IIIe6 and IIIs2 have some potential for horticulture, and possibly cereal cropping, due to the relatively fine soils and relatively equable climate. Frosty and foggy winter conditions restrict the versatility of arable use, but in general there is considerable potential for diversification and intensification of land use in this subsuite. The most important soil conservation measures are those aimed at gully control and minimising soil loss on arable land, e.g., contour cultivation and direct drilling. Much of the presently undeveloped land lies within the Pureora State Forest Park for which little indigenous logging or conversion is prescribed. Some of the small wetland areas, e.g., Kapenga swamp and Lake Ngahewa adjacent to SH 5, have significant although undocumented wildlife and habitat conservation values.

LUC Units on Moderately Deep Fine Taupo Pumice (Table 23)

LUC unit IIIs2 (4**,900 ha)—**Figures 60, 61

This LUC unit occurs on flat to gently undulating terraces mantled with moderately deep Taupo Pumice over deep 'Mo' ashes. It occurs mainly in the Atiamuri and Ngakuru districts, on terraces of the Hinuera Formation. These terraces predate the Taupo eruption and are thus mantled with Taupo Pumice. They generally lie just above Taupo flow tephra surfaces. On the Te Hapua Land Development Block (western Taupo), in the Tahorakuri Forest and the Reporoa Basin, IIIs2 also occurs on flat areas with deeper Taupo Pumice. These areas generally have more coarse-textured soils than in the Atiamuri and Ngakuru district. They were not extensive enough to be distinguished as a separate LUC unit within LUC subsuites 7c or 7d. Areas mapped as IIIs2 in the Reporoa Basin are described by Pain & Pullar (1975) as pre-Rerewhakaaitu and pre-Rotorua fan surfaces.

With no significant erosion potential even under arable use (although windbreaks are required in the West Taupo area for the achievement of maximum agricultural potential), and a high potential for both pastoral and exotic forestry use, IIIs2 has considerable potential for diversification and intensification of use although the present demarcation between exotic forestry (which occupies over 50% of the area) and other uses is unlikely to change markedly. Out of season frosts are the main limitation to horticultural development.

LUC unit IIIe6 **(6,950 ha)—**Figure 61

This LUC unit occurs on undulating to rolling slopes mantled with moderately thick Taupo Pumice. It is scattered throughout the subsuite. It has moderately to strongly leached

TABLE 23: LUC units on moderately deep fine Taupo Pumice.

LUC UNIT	IIIs2	IIIe6	IVe6	IVel 1	VIe17
RELATED LUC UNIT (LUC Suite)	IIIs6,I Illel0| (7f),	VIe9, VIs 2, |VI Ie4			
PHYSIOGRAPHY	Lower | Raised terraces,terraces river flats	Rolling terraces on ignimbrite or sediments	Dissected rolling terraces on uncon- solidated sedi- ments |	Broken hill country on unstable rock types	Hill country'on stable rock types
	4 900	(7c) | (8c)			
	Illel0[1] (7f) I IIIwl,I IVwl [1] (3) | I Depres- sions , I valleys				
	VIel9, [1] IVel3 | <7g) I				
	|				
AREA (ha)		0(0)	18		1 400
SLOPES	PRESENT LAND USE A A + B	Exotic forestry Sheep & cattle Dairying	1Sb	Taupo Tihoi Oruanui Ngaroma	C' C + B C + D
SOILS	Taupo	6 950 B B + C	0-1Sh (2Sh,R; 1Sb,G)		Taupo
% MAP UNITS CONTAINING EROSION			Dairying Exotic forestry Sheep & cattle	1Sh,R,Sb	
PRESENT EROSION	0	Taupo Oruanui Tihoi	15 950	1Sh,G (3Sh,R; 2G,Sb)	71
POTENTIAL EROSION	0		C C + D	Exotic forestry Dairying Undeveloped Sheep & cattle	1G,Sb 1G,Sh

				D		2- 3G; 2Sh,sSl,Sb	Exotic forestry Undeveloped
(3Sh,R,G;	2Sb)	11	200				
Dairying		D + E E		Taupo Ngakuru Haparangi	75	Grazing	
					1- 2Sh,G; lsSl,Sb		

STOCK CARRYING CAPACITY (s.u./ha)	14, 18, 25
SITE INDEX (m)	33-35
	14, 18, 25
	29-36
	14, 18, 23
	27-36
	12, 16, 22
	32-33
	10, 14, 18
	32-35

soils (Oruanui and Tihoi series) in the west, including soil phases (not separately recorded) whose parent materials are colluvial ashes in depressions and small gullies. Although soil conservation measures such as gully control and contour cultivation are necessary for achieving full potential, IIIe6 has considerable versatility and potential for diversification and intensification, particularly in the Ngakuru district. It has a high and very high potential for pastoral and exotic forestry use respectively, as well as being moderately suitable for arable use.

LUC **unit IVe6 (15,950 ha)—**Figures 61, 63

This LUC unit occurs on rolling to strongly rolling slopes mantled with Taupo Pumice. It is scattered throughout the subsuite and is particularly extensive west of Mangakino where it has a relatively deep but fine Taupo Pumice mantle and is widely recorded with hill country LUC units from LUC subsuite 7c (see p. 135). The inventory factors recorded on IVe6 are very similar to those on IIIe6 except for steeper slopes (the two LUC units forming a continuum of slope). It also has a similar land use pattern to IIIe6 although about 25% of its area is undeveloped. Because of its steeper slopes, IVe6 has a greater erosion potential than IIIe6, which decreases its pastoral potential slightly and its cropping potential severely. Cultivation should only occur on the contour and away from ephemeral waterways, and gully control and maintenance of grass cover may also be necessary.

LUC **unit IVell (1,400 ha)—**Figure 62

This LUC unit occurs on predominantly rolling slopes mantled with Taupo Pumice, but differs from IVe6 in having finely dissected slopes and more ephemeral waterways. It occurs only in the eastern part of the subsuite, mainly on unconsolidated lithologies in the Ngakuru Graben. Small areas of Taupo flow tephra or redeposited ashes are often included in IVell, which forms a continuum with IVel3 and Vie 19 (LUC subsuite 7g). However, Taupo flow tephra and soils derived from it were not recorded in the inventory.

IVel 1 has very severe constraints to arable use, caused by its fine dissection pattern, which results in a severe gully and streambank erosion potential, as well as a severe sheet and rill erosion potential due to slope. Occasional winter fodder cropping is the only suitable arable use. However, IVell has a high potential for both pastoral and exotic forestry use, and although it is likely to remain predominantly in pastoral use it would be very suitable for farm-scale woodlots. Soil conservation measures for both forestry and pastoral use would be essential, especially gully and ephemeral waterway control.

LUC **unit VIel7 (11,200 ha)—**Figures 18, 62, 63

This LUC unit occurs on strongly rolling to moderately steep hillslopes on unstable rock types mantled with moderately deep Taupo Pumice. It occurs mainly in the eastern part of the subsuite, with smaller areas in the Mangakino-Whakamaru district. In the eastern area it is mapped as an 'unstable rock' equivalent of VIe5 (LUC subsuite 7a), mainly on Huka Group sediments. In this area it has a contrasting erosion pattern to VIe5, with more gully and streambank erosion on its broken slopes (it forms a continuum with IVell). West of Whakamaru, however, it only occurs in small areas on the terrace deposits around Mangakino and Whakamaru, the rest of the area being underlain by ignimbrite.

Vie 17 is variable in terms of tephra cover and soil. Taupo Pumice is recorded as a significant rock type over approximately 60% of the LUC unit and yellow-brown pumice soils are recorded in these areas. Elsewhere, on the steeper hill slopes south of Rotorua, as Taupo Pumice thins, composite yellow-brown pumice soils on yellow-brown loams (Haparangi series) or yellow-brown loams (Ngakuru series) are recorded. As with IVell, small areas of Taupo flow tephra occur. The erosion pattern is similar to that on IVell, but more severe under pastoral use.

The main land use is sheep and cattle farming, although NWASCO (1982) recommended exotic forestry as a more suitable land use. Because of existing pastoral use a complete change to exotic forestry is not expected but, as with IVell, Vie 17 would be suitable for

farm-scale woodlots. Under pastoral use, control of gullies and minimising of bare ground is essential, while forestry use should conform to the "Forest Operations" guidelines (NWASCO 1976).

Fig, 60: **LUC subsuite 7b: Ills2 on terrace mantled with** fine **Taupo airfall tephra. Hills in background** are **predominantly Vle5 (LUC subsuite 7a), mapped on moderately** deep **Taupo Pumice (see** text). **Upper Atiamuri, N85/527802 looking N.**

": 1.1 **"C subsuite 7b:** Ille6 **(right foreground) and** IVe6 **(left foreground). Flat surface on top** of **terrace in background is** IIIs2. **Twist Rd, Ngakuru district, N85/675848 looking** E.

Fig. 62: LUC **subsuite 7b: IVell, with Vie 17 behind. Scrub-covered hill is mapped as Vllel** (LUC **subsuite 4a). Parsons Rd, Ngakuru district, N85/618845 looking S.**

Fig. 63: LUC **subsuite 7b: Vie 17 on Huka Group sediments. IVe6 in foreground. Waikaukau Rd, Guthrie district, N85/662884 looking NW.**

LUC SUBSUITE 7c: DEEP TAUPO PUMICE IN HIGH RAINFALL AREAS

General

This subsuite is characterised by deep, coarse airfall Taupo Pumice, as is the next subsuite to be described (7d). The two subsuites are distinguished from each other by the amount of rainfall they receive; this subsuite occurs in areas with more than 1300 mm annually ('high' rainfall), and LUC subsuite 7d in areas with less than 1300 mm ('low' rainfall)*. The amount of rainfall received, particularly in summer, has a marked effect on land use capability. In high rainfall areas, cropping versatility may be slightly restricted due to difficulty in ripening some crops, hence the arable LUC units in LUC subsuite 7c are ranked a little lower. However, on non-arable land the soil moisture deficits become limiting and because they are more severe in LUC subsuite 7d its LUC is accordingly ranked lower.

This is the most extensive of the Taupo subsuites, covering 180,600 ha, 23% of the area of the LUC suite or 10% of the total area of the region. Because it is so extensive, this subsuite is very variable. This is especially so for the hill country LUC units, which were widely mapped outside the main area of occurrence, in areas with slightly thinner and finer Taupo Pumice where no separate LUC unit were recognised in LUC suite 7b (see p. 135).

The main area of this subsuite is in the western and northern Taupo districts, bounded by State Highways 30 and 41, the Waikato River, and the Hauhungaroa Range. Within this large area, it is only absent in small areas of steeplands or flow tephra and small areas with less than 1300 mm annual rainfall. Away from this area, the subsuite also occurs to the north-west and north (areas of finer Taupo Pumice), in the hill country north of Atiamuri, in the Paeroa Range-Ohakuri district, in scattered areas to the south and south-east of Lake Taupo, and at its furthest extremity, in the south-west of the Urewera ranges between the Whaeo River and Te Whaiti.

There are six LUC units: Ille8, IVe8, VIs2, Vle9, Vie 10 and VIel6. Other LUC units found within the main area of this subsuite are from Taupo LUC subsuites on steeplands, flow tephra and mixed tephras (7e, f, g), as well as IIIs2 (7b) on flat areas. Related LUC units which border areas of this subsuite are from LUC subsuites 7a, b, d on areas of thinner and finer Taupo Pumice or areas of lower rainfall, as well as from the above subsuites.

C.U:..iate

The climate over most of the area differs from that described for the 'typical' Taupo climate,in being considerably wetter. Rainfall exceeds 2,000 mm annually in many places and a markedly dry summer, while common in the Taupo-Atiamuri region, is by no means universal. High-intensity rainstorms may occur at any time of the year. Temperatures range from cool to hot, and air frosts are not common. Representative climate stations are at Otutira and Pureora Forest (just outside the region). Areas lying at higher altitudes (e.g., Puroora) or within mountain ranges (e.g., Minginui) are distinctly colder.

Physiography

The main part of this subsuite consists of gentle hill country on the western Taupo ignimbrite sheet, at an altitude of 330-650 m a.s.l. Because this area has a particularly thick and deeply eroded tephra cover, it has a more varied relief pattern than do other ignimbrite sheets.

Other areas of the subsuite occur in the following physiographic zones (not shown in Table 24):

a) The lower slopes of the Hauhungaroa Range up to about 720 m a.s.l. which are separated from the west Taupo ignimbrite country by the Hauhungaroa Fault.
b) Andesitic cones lying between the Taupo and Tongariro Volcanic Zones.
c) The pumice breccia country to the east of Lake Taupo, mainly adjacent to the Kaimanawa Fault.

***Although 1300 mm is a comparatively low rainfall for the Bay of Plenty-Volcanic Plateau Region, the description**

d) Extensively faulted hills surrounding and within the Ngakuru Graben.

e) The low eastern greywacke and ignimbrite ranges of the south-west Urewera country.

Nearly 90% of the subsuite has predominantly strongly rolling to moderately steep slopes and the remainder has undulating to rolling slopes. There are only very small flat areas, and these were included within IIIs2 (LUC subsuite 7b). Steepland areas were included in LUC subsuite 7e but hill country mapped in this subsuite frequently contains short steep slopes.

Rock Type and Soil Parent Material

Members of the Taupo Sub-group, including both the Taupo Pumice Formation and Waimihia Formation, occur to a total depth of up to 2 m. Taupo Pumice was recorded over the whole subsuite but on 15% of the area, mainly in steeper hill country, it was recorded as only significant in patches. Older tephras beneath Taupo Pumice are dominated by thick deposits of the Oruanui Formation, both ash and breccia. Where this deeply overlies ignimbrite in the western Taupo area, it has sometimes been mapped as the basal rock type. Other significant tephras include Tongariro Ash, undifferentiated brown tuffs and tephric loess to the south, and various members of the Rotorua Sub-group to the north.

The main basal recorded rock type is stable volcanic rock which may be ignimbrite, rhyolite or andesite. Rhyolitic breccia is common to the south-east and north of Lake Taupo, while smaller areas are underlain by terrace sediments, greywacke or various Tertiary sedimentary rock types (mainly massive sandstone).

Soils

44% of the subsuite was mapped using soils from the Taupo Survey, 26% using soils from the King Country Survey, and smaller areas from the General, Waiotapu and Whakatane Surveys. The main soil groups recorded were moderately to strongly leached yellow-brown pumice soils, reflecting the high rainfall environment (Oruanui and Tihoi series; Taupo series soils were not recorded because they occur in a lower rainfall zone and are included in LUC subsuite 7d). Because of the wide distribution of the subsuite, the variability of tephra thickness on hill slopes, and the fact that VIs2 and VIe9 were mapped in areas of thinner and finer Taupo Pumice (see below), the depth of Taupo Pumice is rather variable and about 20% of the subsuite area has soils other than yellow-brown pumice soils* recorded.

The higher rainfall on this subsuite is reflected by the fact that soils over about 60% of the area are moderately to strongly leached, and often podzolised (e.g., Tihoi, Mangatepopo series). About 10% of the subsuite has soils with Ngauruhoe ash in their parent materials (e.g., Mangatepopo, Kuratau series).

Erosion

Slight erosion was recorded on map units covering 34% of the subsuite and moderate erosion on map units covering 3%. The main type of erosion was sheet, which was recorded on map units covering 34% of the subsuite (nearly 90% of the area affected by erosion). Gully erosion occurred on map units covering 8% of the subsuite while minor erosion forms included soil slip, rill, tunnel gully and streambank. More than 70% of the land with a dominantly pasture cover was mapped as having sheet erosion. Potential erosion is assessed as slight to moderate under pastoral use and the erosion association is classified as association P.

Land Use and Land Management

The present pattern of land use has almost equal portions of pastoral farming, exotic forest and undeveloped land. As well as traditional sheep and cattle farming, deer farming is becoming an increasingly important land use. Only 11% of the subsuite is suitable for arable use, mainly for supplementary fodder crops. However, there is considerable scope for intensification of pastoral use; although pastoral potential for all LUC units is moderately

*These were mainly Ngakuru series; these soils were provisionally classified in the Taupo Survey as composite yellow-brown pumice soils on yellow-brown loams, but are now regarded as yellow-brown loams.

high, most of the present pasture is recorded as unimproved and there are also large areas of mixed pasture and indigenous scrub.

kxotic forestry potentials are generally medium to high. NWASCO (1982) recommends an increase in exotic forestry to about half of the subsuite. This would necessitate both a change from pastoral to exotic forestry use in some areas, and the use of all undeveloped land for exotic forestry. However, much of the undeveloped portion of the subsuite lies within the Pureora and Whirinaki State Forest Parks, which are likely to remain dominantly as indigenous forest areas. Indigenous forestry has been an important land use in the past and continues to the present on both public and private land. Indigenous forest covers 17% of the subsuite, mainly lowland podocarp-hardwood forest, but also including significant areas of beech, hardwood and podocarp forest. Indigenous scrub and scrub/forest mixtures cover a further 15%. Much of this undeveloped land has a very high biological conservation value; it includes the most significant remaining areas of tall lowland podocarp and podocarp-hardwood forest in the North Island, and vital habitats for several endangered animal species (Imboden 1978).

Soil and water conservation measures on developed land are mainly aimed at minimising exposure of bare ground. Exotic forestry on non-arable LUC units should comply with the "Forest Operations" guidelines (NWASCO 1976).

LUC **Units on Deep Taupo Pumice in High Rainfall Areas** (Table 24)

LUC **unit** IIIe8 **(1,450 ha)—**Figure 65

This LUC unit occurs on undulating to rolling land. It is scattered through the northern portion of the subsuite, with the largest area occurring north of Atiamuri. Soils are slightly finer textured than those of other LUC units in the subsuite and there is very little present erosion, although there is a moderate erosion potential under cultivation.

Sheep and cattle raising and exotic forestry occupy nearly 90% of the area. Arable use is limited to minor supplementary fodder cropping but there is a potential for more diversified arable use, as well as for much more intensive pastoral use, with potential stock carrying capacity more than double the present average. Most undeveloped land consists of small patches of indigenous forest within farming areas.

LUC **unit IVe8 (19,050 ha)—**Figures 64, 65, 68

This LUC unit occurs on rolling to strongly rolling land throughout the subsuite area. It is most extensive in the western Taupo district; however, it was not mapped in the Mangakino-Pureora district (see VIe9 below). In the southern portion of the subsuite it has a thin mantle of Ngauruhoe ash (Mangatepopo soils). In other respects it is similar to IIIe8 but has slightly steeper slopes, resulting in higher erosion potentials. However, there is only minor present erosion, probably reflecting the low present degree of development.

Undeveloped land and agricultural land each occupy 35%-40% of the area. Agricultural use includes both cereal and winter fodder cropping as well as grazing. A little indigenous logging occurs in the forested West Taupo areas. Exotic forest occupies the remaining area. IYe8 is capable of development to intensive pastoral use with the aid of soil conservation measures such as gully control, maintenance of a dense pasture cover and contour cultivation. It also has a medium to high potential for exotic forest growth.

LUC **unit VIs2** (**33,700 ha)—**Figures 64, 66, 77

This LUC unit is extensive on strongly rolling hill country throughout the subsuite, especially in the west where it backs onto steeper and higher parts of the Hauhungaroa Range mapped in LUC subsuite 7e. It also occurs in the Rangitoto Range, the Mangakino district and north of the Waikato River between Whakamaru and Atiamuri where fine-textured Taupo Pumice occurs to a depth of 30-40 cm. In these areas, VIs2 and VIe9 (below) were a 'best fit' because there were no equivalent hill country LUC units in LUC subsuite 7b to fit this situation; therefore, these two LUC units were mapped in association with arable LUC units from LUC subsuite 7b. Ngaroma and Maroa soils were mapped in these areas; elsewhere the main soils were moderately leached to strongly podzolised yellow-brown pumice soils (Tihoi and Oruanui series). Podzolised soils were recorded on 60% of the area. VIs2 grades into VIsl (LUC subsuite 7a) as Taupo Pumice becomes shallower.

TABLE 24: LUC units on deep Taupo Pumice in high rainfall areas.

LUC UNIT	IIIe8	IVe8	VIs2	VIe9	VIe16	VIe10
RELATED LUC UNIT (LUC Suite)	IIIs21 (7b)		IVel3 (7g) IVe6 1 (7b)	Ivile6 (7e)		VIIe7 t (7e)
PHYSIOGRAPHY	1	----------VYfcioL IcLU	po ignimbrite sheet	i	(with ignimbrite outcrops)	(overlain byi breccia) I
AREA (ha)	1 450	19 050	33 700	79 800	9 650	37 000
SLOPES	B + C B	C C + D	D D + E D + C	E E + F E + D	E E + F D	E D + E D + E
SOILS	Oruanui Tihoi	Oruanui Tihoi Mangetepopo	Tihoi Oruanui Ngaroma	Oruanui Tihoi Ngakuru	Oruanui Ngakuru (Bare rock)	Oruanui Mangatepopo Ngakuru
% MAP UNITS CONTAINING EROSION	9	17	25	41	65	48
PRESENT EROSION	1G	lSh,G	lSh,G	l-2Sh; 1G,sS1	l-2Sh; lsSl,G	l-2Sh; 1G,R
POTENTIAL EROSION	0(2G,Sh,R)	lSh(3Sh,R; 2G)	lSh,G	2Sh,sSl; 1G	2Sh,G,sSl	2Sh,G,sSl
PRESENT LAND USE	Sheep,cattle,deer Exotic forest Undeveloped	Sheep,cattle,deer Undeveloped Exotic forestry Indigenous logging	Undeveloped Exotic forestry Sheep,cattle,deer Indigenous logginc	Undeveloped Sheep,cattle,deer Exotic forestry Indigenous logging	Sheep & cattle Undeveloped Exotic forestry Indigenous logginc	Sheep,cattle,deer Exotic forestry Undeveloped
STOCK CARRYING CAPACITY (s.u./ha)	11, 18, 23	10, 16, 20	10, 12, 16*	12, 14, 16	10, 11, 15	12, 14, 16
SITE INDEX (m)	27-30	28-30	23-35	21-34	27-33	25-34

VIs2 has a characteristically rounded topography. Minor sheet erosion is extensive but under good pastoral management erosion potential is assessed only as slight. Therefore the limitations of soil fertility and texture are judged to be more significant. About 45% of the area is presently undeveloped, exotic forest occurs over about 35% and extensive grazing on just over 20%. Extensive indigenous logging has occurred in the past. The potential for pastoral use is moderately high and that for exotic forestry is medium to high. Soil conservation measures aimed at reducing sheet erosion are necessary if pastoral potential is to be achieved.

LUC unit **VIe9 (79,800 ha)—**Figures 66, 74, 84, 103

This LUC unit occurs on predominantly moderately steep hill country on stable underlying rocks throughout the subsuite. It was also mapped to the north of the subsuite and in the King Country on areas of finer Taupo Pumice, in the same way as VIs2. In particular a very large area centred in the Mangakino-Pureora district was mapped as an intermixture of VIe9 and IVe6 (LUC subsuite 7b) (see above). VIe9 grades into VIe5 (LUC subsuite 7a) as Taupo Pumice becomes shallower. In the southern Rangitoto Range VIe9 rises to an altitude of 800 m a.s.L, rather higher than the rest of the subsuite. In these areas VIc1 (LUC subsuite 7e) or VIe21 (LUC subsuite 8a) may have been more appropriate.

VIe9 is similar to VIs2 but, because it is slightly steeper and more broken and has a greater erosion potential, erosion has been assessed as the dominant limiting factor. Soils are mainly Oruanui and Tihoi series but in the Whakamaru area, where rainfall is a little lower, a complex of Ngakuru and Taupo soils have been mapped, indicating thinner Taupo Pumice on steeper slopes and thicker Taupo Pumice on lower colluvial slopes and intervening gullies. The underlying rock type is almost always ignimbrite.

The present land use pattern is similar to that on VIs2 except for a smaller, but increasing, proportion of exotic forestry. Because the LUC unit is very widespread, pastoral and exotic forestry potentials are rather variable and it is difficult to predict land use trends.

LUC **unit VIel0 (37,000 ha)—**Figures 64, 67, 78

This LUC unit occurs on strongly rolling to moderately steep hills on unstable rock types throughout the subsuite, particularly north of Taupo and east of Turangi. Its distribution is controlled by the underlying rock types, which are mainly Oruanui Breccia and a smaller area of terrace sediments at Mangakino. Vie 10 does not occur in such a high rainfall environment as VIe9 and VIs2 and podzolised soils occur only in the area around Turangi. It has fewer steep slopes than VIe9 and shows a fairly rounded relief. Much colluvial material and some flow tephra occur in the gullies and in this respect Vie 10 is similar to Vie 19 (LUC subsuite 7g). It has a potential for more severe gully erosion than does VIe9.

Present land use is dominated by grazing, but exotic forest and scrubland together occupy about 40% of the area. It has similar pastoral and exotic forestry potentials to VIe9 but probably requires a greater input of soil conservation work to maintain these potentials.

LUC **unit VIel6 (9,650 ha)—**Figure 68

This LUC unit is generally similar to VIe9 but distinguished from it by the presence of frequent ignimbrite outcrops, giving rise to short steep slopes and a broken landscape rather similar in appearance to hilly areas on the Mamaku Plateau (VIell, LUC suite 5). This LUC unit has a more restricted distribution than others in the subsuite, occurring only in the Western Taupo district between Whakamaru and Kuratau. Like VIe9, Vie 16 has a variable thickness of Taupo Pumice, resulting in complexes of yellow-brown loams and yellow-brown pumice or composite soils. This variation is due to the proximity of ignimbrite to the surface in places, as well as to colluvial processes. VIel6 has a similar pattern of erosion to that on Vle^ but has a greater incidence of sheet erosion.

About 60% of the area is in well-established pastoral use. Exotic forestry occurs on about 10% with the remainder being undeveloped indigenous scrubland within pastoral areas. Under pastoral use there is a continuing erosion risk, especially for sheet erosion, and only a moderate stock carrying potential. Exotic forestry potential is variable due to shallow soils and poor drainage in places.

i¥e8

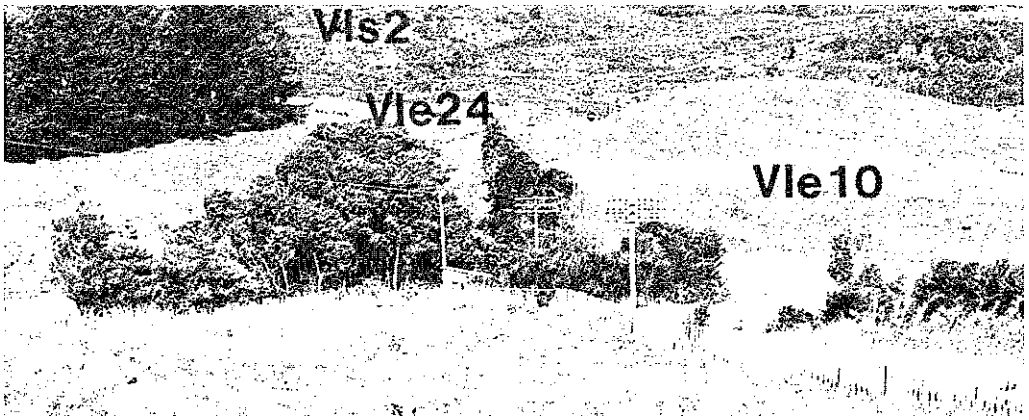


Fig. 64: **LUC subsuite 7c: General view of subsuite in West Taupo district, with IVe8, VIs2 and Vie 10 on thick Taupo airfall and flow tephra over Oruanui breccia and Kakaramea andesite. VIe24 (LUC subsuite 7f) in basin near road. Pukawa Development Block, N102/197131 looking SSE.**

*-f'--

!Ve8

Fig. 65: LUC subsuite 7c: IIIe8 (foreground) and IVe8 (background). Ben Lomond Rd, northern Taupo district, N94/506456 looking N.

g. **66:** LUC **subsuite 7c: VIe9 (foreground) and VIs2 (background) on ignimbrite. Rapid weed reversion on cleared land. Whanganui catchment, western Taupo district, N102/140278 looking** N.

g. **67:** LUC **suite 7c: VIelO on deep Oruanui breccia, showing sheet erosion on steep slopes. Mapara Rd, northern Taupo district, N94/487442 looking S.**

Fig. **68:** LUC **suite 7c:** Vie **16 on Whakamaru ignimbrite with frequent outcrops. IVe8 in foreground. Whakamaru district, N84/260616 looking SSE.**

LUC SUITE 7d: DEEP TAUPO PUMICE IN LOW RAINFALL AREAS

General

This subsuite occurs in areas of deep coarse Taupo Pumice where annual rainfall is less than 1300 mm and there are pronounced summer moisture deficits. The 1300 mm isohyet was chosen to distinguish this subsuite from the previous LUC subsuite because it marks the boundary between weakly to very weakly leached and moderately leached yellow-brown pumice soils. Although these two groups of soils (principally Taupo and Oruanui series respectively) have many common properties, differences in climate and underlying lithology result in important differences in land use capability between the two subsuites. Other Taupo subsuites also contain considerable areas where annual rainfall is less than 1300 mm, notably those on Taupo flow tephra and complexes of Taupo tephras (7f, g). These are often mapped in adjacent areas to this subsuite. The subsuite is bordered by several other Taupo subsuites into which it grades.

The distribution of the subsuite centres around and to the north of Lake Taupo (Fig. 55). The largest areas occur north of Taupo in the vicinity of Wairakei, Tahorakuri Forest, the Broadlands and Reporoa Basins and along the Waikato River valley in the Ohakuri-Atiamuri district. Around Lake Taupo it is found in the Whanganui-Karangahape area in the west, south of Marotiri settlement in the north-west and in the Hatepe area in the east. Small areas are also scattered in the Ngakuru and Waikite Valleys, where Taupo Pumice is slightly finer and shallower than elsewhere in the subsuite.

The subsuite has an area of 38,500 ha, 5% of the Taupo LUC suite and 2.2% of the total area of the region. It contains six LUC units: IIIe7, IVe7, VIs3, VIel3, VIel4 and VIIel3. They are differentiated by slope, and, for the non-arable LUC units, also by underlying rock type. Flat areas and most steep areas within the subsuite are included in LUC subsuites 7b and 7e respectively.

Climate

The main climatic characteristic is low rainfall, particularly between January and April. However, severe localised rainstorms can occur at any time of the year. Summer temperatures are high and winter temperatures cool. Areas west of Taupo are a little higher in elevation and cooler, while areas north of Taupo are slightly moister. The representative climate station is Taupo.

Physiography

North of Lake Taupo, the subsuite occurs mainly within the Broadlands-Reporoa Basin and on terraces and river valleys in the Ngakuru Graben. In the west, the subsuite occurs on the west Taupo ignimbrite country, and in the east, on the dissected breccia terraces and hills to the east of Lake Taupo. Most of the subsuite occurs on land of moderate relief. However, about one-third of this area is on moderately steep to steep breccia hill country, which is sometimes dissected.

Rock Type and Soil Parent Material

Very thick tephra deposits mantle all land in this subsuite. Both Taupo Sub-group and underlying 'Mo' tephras down to Oruanui Ash were recorded throughout most of the subsuite. Taupo Sub-group tephras included some flow tephra, and significant thicknesses of lapilli. The latter was occasionally recorded separately (notably in Vile 13), but areas where Waimihia lapilli was especially significant were classified into LUC subsuite 7i.

The most common underlying rock type is pumice breccia, recorded as Ft. This was mapped as Waitahanui and Wairakei Breccias by Grindley (1960), and since correlated with Oruanui Breccia (Pullar & Birrell 1973a; Vucetich & Pullar 1969). Other rock types classified as 'unstable' include Haparangi Rhyolitic Pumice, members of the Huka and Ohakuri Formations, and various terrace deposits. Rock types mapped as Ft or Us underlie about 40% of the subsuite. Stable underlying rock types, including Whakamaru Ignimbrite in western Taupo, Rangitaiki Ignimbrite in the eastern Reporoa-Broadlands Basin, and small areas of sandstone in the Ohakuri Formation, underlie about 25% of the subsuite.

Soils

Soils from the Taupo and Waiotapu Surveys were each recorded on 48% of the subsuite. The remaining small areas were mapped using soils from the General Survey and the King Country Survey. Taupo soils were by far the most common recorded, covering more than 90% of the area of the subsuite. About half of these are hill soils. Of the rest, deep phases of Taupo soils are common, while Taupo eroded complex has been recorded where Taupo Pumice includes flow tephra and where post-Taupo eruption erosion has resulted in small dry gullies (see below). East of Lake Taupo, small areas of yellow-brown pumice soils primarily derived from flow tephra have been recorded. On the steepest areas, small areas of steepland soils related either to yellow-brown pumice soils or to composite yellow-brown pumice soils on yellow-brown loams have also been recorded. Note that not all Taupo soils occur in this subsuite. Especially where they have been mapped in the General Survey and contain finer Taupo Pumice, they have been widely recorded in LUC subsuite 7b and to a lesser extent in other Taupo subsuites.

Erosion

Slight erosion was recorded on map units covering 30% of the subsuite and moderate erosion on map units covering 4%. Sheet and gully were the most important erosion types, and were roughly equal in importance, both at minor and moderate severity. Minor erosion types recorded included rill, tunnel gully and streambank. Potential erosion is assessed as moderate to severe. The erosion association is classified as mainly association P with association R on some of the arable land.

Gully erosion in the Torepatutahi Catchment in the eastern Reporoa Basin was described by Healy (1967). He also described the morphology of eroded stream channels in detail and concluded that most erosion associated with recent land development had occurred in upper Taupo Pumice Formation members after heavy rainfall. He drew attention to the similarity of recent erosion to that which occurred immediately after the Taupo eruption and gave rise to the present system of ephemeral waterways in the Taupo Volcanic Zone.

Land Use and Land Management

Land in this subsuite has been rapidly developed in the last few decades. Only about 10% of the area was undeveloped at the time of mapping; much of this has since been developed for exotic forestry in Lake Taupo State Forest and Tauhara Forest. Most of the remaining undeveloped land is covered by scrub which occurs in small patches on developed farmland or is already committed for exotic forestry. Overall, sheep and cattle farming (especially breeding) is the most important land use, covering just under 50% of the subsuite, while exotic forestry covers about 40%. Some dairying occurs in the Reporoa-Atiamuri district. Winter fodder cropping and lucerne are important.

No major changes in land use are anticipated on the arable land where the potential for present uses is high and there is considerable scope for intensification. In general, land in this subsuite is not suitable for continuous arable use. On the non-arable land, grazing potential is severely limited by summer moisture deficits which are aggravated by topography and grass grub infestation. However, exotic forest potential is generally high; for this reason, a trend from extensive grazing to exotic forestry can be foreseen, as well as development of the remaining remnants of undeveloped land for exotic forestry.

Soil conservation practices are mainly aimed at maintenance of a complete grass cover (including control of grass grub) and gully control. They are essential for full productivity on all but the most gently sloping land. Compliance with the "Forest Operations" guidelines (NWASCO 1976) is also desirable for forestry on non-arable land, while erosion control or protection forestry may be more suitable for the steepest and most dissected areas. A few very small areas are included in scenic reserves around Lake Taupo.

LUC Units on Deep Taupo Pumice in Low Rainfall Areas (Table 25)

LUC unit IIIe7 (8,700 ha)—Figure 69

This LUC unit occurs on undulating to rolling slopes, mainly north of Wairakei in the vicinity of Tahorakuri Forest and along the western side of the Reporoa Basin. It is also scattered through the Ngakuru-Atiamuri district and to the north-west of Lake Taupo.

A deep tephra cover largely masks the underlying rocks. Soils are coarse textured and relatively infertile, and are subject to the climatic limitations discussed above. However, the generally mild temperatures and easy relief give a high potential for both pastoral and exotic forestry use. Arable use is mainly for supplementary winter fodder cropping but could potentially include occasional cereal crops. There is a considerable potential for intensification of pastoral use, but the high potential stock carrying capacity is dependent on good pasture management and the application of soil conservation techniques. Contour cultivation is a requirement for arable use.

Present land uses are exotic forest (about 40%), and sheep and cattle raising. Both uses are well established and their balance appears likely to remain.

LUC unit IVe7 (8,000 ha)—Figures 18, 69, 70

This LUC unit is very similar to IIIe7, the main difference being a slightly steeper or more variable slope and much greater incidence of sheet erosion. It also has a similar distribution to IIIe7. IVe7 has a lower potential stock carrying capacity and slightly more variable exotic forestry potential than IIIe7, but because its present use is less intensive there is equal scope for intensification if appropriate soil conservation measures are applied. Because of its slope and consequent erosion hazard, IVe7 is marginal for arable use, which is generally confined to occasional supplementary fodder cropping. Only about 20% is presently used for exotic forestry, although this proportion may expand to include small undeveloped areas which presently account for about 10% of the area.

TABLE 25: **LUC units on deep Taupo Pumice in low rainfall areas.**

LUC UNIT	**Ie7**		**Vls3**		**Vie 14**
RELATED LUC UNIT (LUC Suite)	IIIelO, IVs4 (7f)	IVel3 (7g)	I V e 7	V 'VIIe6 l(7e) e 1	I v i l e 7
PHYSIOGRAPHY	River valleys and basins	River terraces and rolling slopes	Easy ignimbrite hill country	Unstable 'hill country I Vil e 13	I (7 e) Dissected hills near lake shore
AREA (ha)	IIIs21 (7b) |	2 800	3		
SLOPES					
SOILS					
% MAP UNITS CONTAINING EROSION					
PRESENT EROSION					
POTENTIAL EROSION					
PRESENT LAND USE	8 700	Taupo	lSb,G	C + B C + D	lSh,G
	B + C B		0(2G,Sh,R)	Taupo	lSh,G (3Sh,R; 2G)
			Sheep & cattle Exotic forestry 8 000		Sheet & cattle Exotic forestry Undeveloped
		13	C	38	

D
D + E

Taupo

24

ISh

ISh

Exotic forestry
Sheep & cattle
Undeveloped

6 050

E
E + F
E + D

Taupo

62

1-2Sh,G

2G,Sh; lsSl

Exotic forestry
Sheep & cattle
10 850

E
D

D + E

Taupo

42

1-2Sh,G

2Sh,G; lsSl

Exotic forestry
Sheep & cattle
Undeveloped
2 100

E'
D'
F

Tauhara
Taupo
Otamatea

14

1Sh,G

3Sh,G

Undeveloped
Exotic forestry

STOCK CARRYING CAPACITY (s.u./ha)	14, 18, 23	
SITE INDEX (m)	30-33	28-32
	12, 18, 20	
	28-34	
	11, 12, 20	
	23-34	
	11, 12, 14	
	27-34	
	11, 12, 14	
	25-34	

LUC unit VIs3 (2,800 ha)—Figure 70

This LUC unit occurs on strongly rolling to moderately steep areas on stable underlying rock types. It has no significant erosion hazard under good pastoral management. It occurs in scattered areas between the northern Reporoa district and Atiamuri which are underlain by ignimbrite but have not been deeply mantled by Oruanui Breccia. There are smaller areas north-west of Lake Taupo and behind Karangahape Trig on western Lake Taupo. It was also mapped in the Waikite Valley.

Compared with IVe7, VIs3 has slightly finer soil texture but greater relief, resulting in a similar pastoral potential. Present land use is evenly divided between pastoral use (sheep and cattle grazing) and exotic forestry. Exotic forestry potential is rather variable. Under good pastoral management erosion should not be a significant problem, but management should aim to maintain a complete pasture cover.

LUC unit VIel3 (6,050 ha)—Figure 71

This LUC unit occurs on predominantly moderately steep slopes overlying ignimbrite. It is scattered along the Waikato River between Taupo and Atiamuri, along the fringes of the Reporoa Basin and on the lower slopes of Mount Tauhara. Vie 13 differs from VIs3 chiefly by its steeper slopes and the frequent incidence of gully erosion. The steeper slopes result in a significantly higher incidence of erosion, greater susceptibility to moisture deficits, and correspondingly lower potential stock carrying capacity. However, this does not significantly alter the exotic forestry potential. Present land uses are exotic forestry and sheep and cattle breeding, in roughly equal proportions. Exotic forestry is expected to expand to include small areas of scrub-covered land and possibly some of the steeper low-producing pastoral areas.

LUC unit VIel4 (10,850 ha)—Figures 69, 72

This LUC unit occurs on strongly rolling to moderately steep hill country throughout the subsuite on unconsolidated breccia, rhyolitic pumice and terrace deposits. VIel4 was separated from Vie 13 on the basis of underlying rock types but, because of the deep tephra cover, the two LUC units are very similar except for slightly easier and shorter slopes in Vie 14. They are both affected by the same types of erosion (predominantly sheet and gully) although, surprisingly, Vie 14 appeared to have a significantly lower proportion of its area affected by present erosion. Present land use and land management is similar to that described for Vie 13. Exotic forest at present occupies about half of the area and may be expected to dominate land use in the future because much of the presently undeveloped land is scrub associated with exotic forest.

LUC unit VIIel3 (2,100 ha)—Figure 73

This LUC unit occurs on dissected hill slopes in the south-east of the subsuite on Taupo tephra and lapilli overlying breccia. This is a localised LUC unit, being confined to the Hatepe-Waitahanui area of the eastern shore of Lake Taupo. It lies adjacent to the presumed Taupo eruption vent at Horomatangi Reef and is mantled with extremely deep and stratigraphically complex Taupo Sub-group deposits, including especially deep Hatepe and Waimihia Lapilli, overlying deep Oruanui Breccia. The land surface of Vile 13 has a very distinctive rilled and dissected appearance which is thought to be related to erosion that occurred immediately after the Taupo eruption. The severe erosion potential which exists on this land has been recognised by the creation of a separate LUC unit. Vile 13 is similar to VIIe7 (LUC subsuite 7e) which has been mapped in the same general area, but the latter is generally steeper and less dissected. VIIel3 is also similar to VIIel4 (LUC subsuite 7i) but differs in its climate, lying mainly within the 1200 mm isohyet.

As well as Taupo series, soils include related steepland soils (Tauhara series), and some yellow-brown pumice soils formed on flow tephra. Present erosion is slight because the LUC unit has an intact vegetation cover dominated by indigenous scrub, mainly manuka and fern species. There is no present pastoral use and this is not recommended. Exotic forestry potential is variable but high in parts. Forestry development should comply with the "Forest Operations" guidelines (NWASCO 1976). Some parts would be more suited to erosion control forestry or catchment protection.

Fig. 69: **LUC subsuite** 7d: **General view of subsuite in eastern Reporoa Basin, looking towards the Kaingaroa Plateau. IIIe7 and IVe7 in foreground, Vie 14** in **background. A small strip of Taupo flow tephra (IllelO and Vllel2, LUC** subsuite **7f) is** in **middle of photograph. Broadlands district, N 85/837640 looking E.**

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mm

Fig. 70: LUC subsuite 7d: IVe7 (foreground) and VIs3 (background). Sheet, rill and gully erosion during pasture renewal. **Note depth of redeposited ashes** against **tree** on **right, following earlier erosion.** Western **Taupo district, N93/262499 looking ESE.**

SIB 10

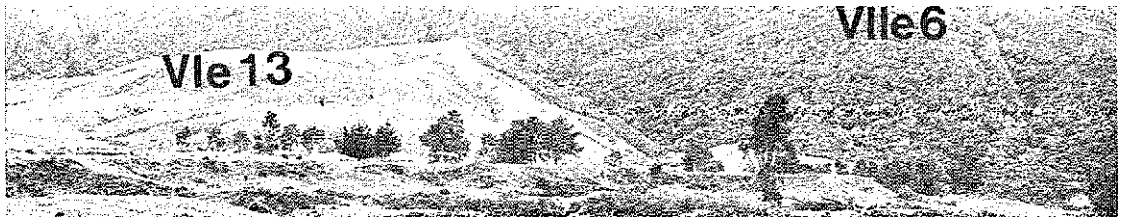

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Fig. 71: LUC subsuite 7d: Relationship between Vie 13 and VIIe6 (LUC subsuite 7e) on Mt Tauhara. Area in foreground is on Taupo flow tephra (LUC subsuite 7f, predominantly VIIel2). Mt Tauhara, N94/614345 looking NNE.

Fig. 72: LUC subsuite 7d: VIel4 on Huka sediments, subject to sheet erosion. Western Kaingaroa Forest (LUC subsuite 7h) in background. Rakau Rd, Broadlands district, N8 5/874622 looking S.

Fig. 73: LUC subsuite 7d: Vile 13, showing historic erosion pattern on deep Taupo Sub-group deposits. Hatepe Hill, N103/458145 looking NE.

LUC SUITE 7e: TAUPO PUMICE ON STEEPLANDS AND MOUNTAINS

General

This subsuite comprises steepland and mountain country which has a significant depth of Taupo Pumice in its soil parent material. The subsuite is unusual in that it is almost entirely comprised of one LUC class (VII) and that there is no slope continuum between its LUC units. These are usually associated with LUC units on deep Taupo Pumice (LUC subsuites 7c and 7d) and often form a continuum with them. However, the steepland and mountainland areas are quite distinctive in the landscape, existing either as uplifted mountain blocks or as steep volcanic cones; even though there are significant differences between these two environments, they have enough shared characteristics which distinguish them from the rest of the Taupo LUC suite to warrant grouping them into a separate subsuite. Mountain areas without a significant mantle of Taupo Pumice, both within and surrounding the subsuite, are mapped in the general steepland LUC subsuite (8a). In this subsuite both tephra cover and underlying rock type are important in determining land use capability, whereas in LUC subsuite 8a the underlying rock type is much more significant.

The two largest areas in this subsuite are the steep rhyolitic cones of the Maroa Volcanic Centre, and the Hauhungaroa Range (Fig. 55). Other areas include mountainlands in the southern Taupo Volcanic Zone, e.g., Mt Pihanga, steepland areas and gullies in the south-eastern Taupo district and the fringes of the Kaimanawa Range, and scattered areas in the south-western Urewera ranges and western Taupo district. The subsuite is widely mapped with various other Taupo subsuites and with LUC suite 8 as discussed above.

The area of this subsuite is 55,600 ha, 7% of the Taupo LUC suite and 3.1% of the total area of the region. There are only four LUC units: VIIe6 and VIIe7 on steeplands, differentiated by underlying rock type, and VIcl and VIIcl on flatter areas, differentiated by altitude.

Sig 10*

Climate

No climate stations are situated within this subsuite. Compared with the 'typical' Taupo LUC suite climate, the main differences would be generally higher rainfall, lower temperatures and stronger winds. Areas in the south would approach the extremes of mountain climate described in LUC suite 8. Other areas would receive considerably less rainfall, e.g., areas around Taupo (Tauhara soils). The subsuite rises to nearly 1100 m a.s.l. in the south of the region although it is not common above 900 m a.s.l.

Physiography

The main areas in this subsuite, e.g., Hauhungaroa Range, Maroa Volcanic Centre, fringes of the Kaimanawa and Urewera Ranges, etc, have been described previously. The subsuite also occurs on the Paeroa Range, an uplifted ignimbrite fault block bounded to the west by the Paeroa Fault and overlain in the south by irregularly dissected breccias (Ohakuri Formation). 90% of the subsuite is steep or moderately steep to steep. (Very steep slopes are included in LUC suite 8). The remaining portion, dominantly rolling to strongly rolling, comprises mountain tops above 850 m a.s.l. which have a dominant climate limitation.

Rock Type and Soil Parent Material

An extremely variable cover of both Taupo and Rotorua Sub-group tephras occurs in this subsuite. Rotorua Sub-group members are prominent in the Maroa Volcanic Centre, while to the south, Taupo Pumice and the underlying Waimihia Formation are thicker. Lapilli was not, however, recorded in the rock type inventory. Taupo Pumice itself was mapped as a significant rock type on just under 80% of the subsuite, including about 10% where it was only significant in patches. Tephra cover was not studied in detail because of problems of accessibility, but the significance of underlying tephras in the erosion pattern of these steeper lands may need future study.

The main underlying rock type is hard volcanic rock, which was recorded on about 60% of the subsuite. This mainly comprises extruded rhyolitic domes (Haparangi Rhyolite), with smaller areas of ignimbrite and andesite. Greywacke of the Urewera, Kaimanawa and Hauhungaroa Ranges underlies about 25% of the area, and various pumice breccias about 10%. Remaining areas are underlain by Tertiary sedimentary rocks, mainly sandstone between the Hauhungaroa Ranges and Mt Pihanga.

Soils

Just under 50% of the area of the subsuite was mapped using soils from the Taupo Survey, about 20% each using soils from the King Country and Waiotapu Surveys, and small areas from the Whakatane and General Surveys. Nearly 80% of the subsuite has steepland soils related to yellow-brown pumice soils, yellow-brown loams or composite soils. Many of them are podzolised but others occur in low rainfall environments. Ngauruhoe ash is widespread in the south and Kaharoa Ash in the north-east but on steepland slopes neither is particularly significant in the soil horizon.

Erosion

Slight erosion was recorded on map units covering 36% of the subsuite, and moderate erosion on map units covering 11%. The most significant erosion type was sheet, affecting map units covering 26% of the area. It was by far the most significant erosion type at moderate severity. Soil slip and gully erosion affected map units covering 16% and 14% of the subsuite respectively, but were generally recorded only at slight severity. Debris avalanche was recorded in small areas.

It is significant that sheet erosion predominates over soil slip in this subsuite, in contrast to LUC subsuite 8a on general steeplands. The main difference between these two subsuites is the greater thickness of Taupo Pumice on the former, and this therefore supports the assertion that Taupo ashes are more susceptible to sheet erosion whereas more weathered 'Mo' ashes are more susceptible to soil slip. Most of the sheet erosion occurs in dominantly pastoral areas which are almost all affected by erosion, frequently at moderate severity. In contrast, erosion was recorded on less than 40% of map units with a dominantly scrub or

forest vegetation cover. Almost all this erosion was of slight severity, and sheet was less important than soil slip, gully or debris avalanche.

Potential erosion was assessed as being slight to severe and the main erosion association classified as association P.

Land Use and Land Management

More than 60% of the subsuite is undeveloped, with indigenous forest covering about 35%. This is mainly podocarp-hardwood forest, both lowland and mid-altitude, but also includes beech forest. Indigenous scrub or forest-scrub mixtures occur over about 20% of the area, and there are small areas of subalpine tussock communities. Grazing occupies about 20% of the subsuite and exotic forestry about 17%. There are considerable areas of very extensive grazing land containing frequent patches of indigenous scrub. There are also extensive areas of self-sown pine trees in reverting indigenous scrub, especially in the southern Paeroa Range.

LUC units in this subsuite have generally low potentials for both grazing and exotic forestry. The high-altitude areas with a climatic limitation have such low production potentials that they are unlikely to be used. VIIe6 and VIIe7 are also generally unsuitable for pastoral use except for small areas that may be managed in conjunction with less steep or lower-lying land. Soil and water conservation measures required for any agricultural use include minimising bare ground, gully control through stock retirement, and open planting of potential slip faces. However, parts of both VIIe6 and VIIe7 have a high exotic forestry potential (although this is extremely variable) and are clearly more suited to exotic forestry than to pastoral use. Compliance with the "Forest Operations" guidelines (NWASCO 1976) is essential on all land in the subsuite.

Parts of the subsuite where the potential for exotic forestry is low would be most suitably retained for catchment protection. Most parts of the subsuite which occur within the Whirinaki, Kaimanawa and Pureora State Forest Parks are reserved for this in the management plans for these forests. They are also of very high habitat conservation quality. Some scenic reserves, notably in the Paeroa Range, occur within the subsuite.

LUC **Units on Taupo Pumice on Steeplands and Mountainlands** (Table 26)

LUC **unit VIIe6 (44,100 ha)—**Figures 71, 74, 75, 103

This LUC unit occurs on predominantly steep slopes on stable rock types mantled by Taupo Pumice. It is by far the most extensive and varied LUC unit in the subsuite. It occurs throughout most of the Taupo Pumice LUC suite area, and has a wide range of soils, which particularly reflects the variation in annual rainfall. Some areas receive less than 1300 mm (Tauhara and Motumoa series), while others receive well over 2000 mm and have podzolised soils (Urewera and Pihanga series). Other soils are influenced by either Ngauruhoe ash in the south (Pihanga series) or Kaharoa Ash in the north (Urewera series).

About 65% of VIIe6 is undeveloped, with a range of indigenous forest and scrub vegetation types. The remainder is divided between exotic forestry and extensive grazing. Productive potentials are very varied, particularly for exotic forestry.

LUC **unit VIIe7 (7,250 ha)—**Figures 76, 85, 87

This LUC unit occurs on predominantly steep slopes on unstable rock types mantled by Taupo Pumice. Its distribution is more restricted than that of VIIe6, being mainly on breccias in the Lake Taupo district, with smaller areas adjoining the western edges of the southern Kaingaroa Plateau and in the Ohakuri-southern Paeroa Range district. These districts have less rainfall than the Maroa district and the mountain ranges, so that VIIe7 is predominantly a 'low rainfall' LUC unit (cf. LUC subsuite 7d) and has few areas of podzolised soils. Slopes tend to be slightly shorter and more broken than those of VIIe6, and hill soils have been recorded on a significant area. Soil slip and debris avalanche were not recorded because these types are usually more characteristic of wetter mountain environments in which VIIe6 was mapped. However, gully erosion is potentially more serious than on VIIe6 because of the unstable underlying rock type.

TABLE 26: LUC units on Taupo Pumice on steeplands and mountainlands.

LUC UNIT	Vlle6	Vlle7	Vlc1	Vlld
RELATED LUC UNIT (LUC Suite)	VIe9 ' (7c) | 1	I VIelO (7c) |	I Vile6 , (7e) [1] 1	|vilie3 [1] (8a) 1
PHYSIOGRAPHY	i 1 Rhyolite j dome s	I Broken country on pumice breccia 1	Lower J Rolling mountain slopes slopes | (above 850r	mountain ^ (above 900m) ") _L/
	1 I	1 1	L------	Steep upper moun-
	i / ^ y .	1 i y\		tain slopes
AREA (ha)	44 100	*1* 250	3 150	1 100
SLOPES	F F + E	F F + E	D D	C
	F + G	F + G	C + E	
SOILS	Urewera Tauhara	Tauhara Taupo	Tihoi Mangatepopo	Tihoi
	Motumoa	Motumoa		
	Pohaturoa			
% MAP UNITS CONTAINING EROSION	51	62	0	0
PRESENT EROSION	l-2Sh,G; lsSl,daF	l-2Sh; 1G	0	0-1W
POTENTIAL EROSION	3Sh; 2G,sSl,daF	3Sh,G	1W, Sh	2W, Sh
PRESENT LAND USE	Undeveloped Extensive grazing Exotic forestry	Undeveloped Extensive grazing Exotic forestry	Undeveloped	Undeveloped
STOCK CARRYING CAPACITY (s.u7ha)	7, 8, 10*	10, 10, 11	-, -, 8	-, 5
SITE INDEX (m)	16-30	27-34	20-23	0*

Land uses are the same as those on VIIe6 although only about 40% of the area is undeveloped. Stock carrying potential is marginally higher than for VIIe6 and exotic forestry potential is generally much higher. This LUC unit is very suitable for exotic forestry, provided the "Forest Operations" guidelines (NWASCO 1976) are carefully adhered to.

LUC unit VIcl (3,150 ha)—Figure 77

This LUC unit occurs on rolling to strongly rolling slopes on stable rock types mantled with deep Taupo Pumice, at an altitude of 850-900 m a.s.l. It occurs on the Hauhungaroa Range between Mt Pureora and Mt Hauhungaroa and in the Kakaramea—northern Tongariro area*. Soils are podzolised yellow-brown pumice soils, in places with a mantle of Ngauruhoe ash. It has low pastoral and exotic forestry potentials (these are estimates only because the LUC unit is completely undeveloped, with a predominantly mid-altitude podocarp-hardwood forest cover).

LUC unit VIIcl (1,100 ha)—Figures 74, 77

This LUC unit is very similar to VIel except that it lies at a higher altitude (900-110m a.s.l.) which results in a more severe potential for wind and sheet erosion and a lower assessment of both pastoral and exotic forestry potentials. VIIcl occurs in the same area as VIel and, like the latter, is completely undeveloped. A small area occurs on the eastern flanks of Mt Ngauruhoe; this may have been more appropriately included in LUC subsuite 6c. VIIcl has a very low estimated pastoral potential and is unsuitable for exotic production forestry (although some exotic conifers can be established at this altitude). Both VIcl and VIlcl lie within state forest park or scenic reserve and it is not anticipated that they will be developed.

*In the Taranaki-Manawatu region, some land with similar soils at approximately the same altitude (Taurewa area) has been classified as LUC class IV because it is fiat and can be cultivated. In the Bay of Plenty-Volcanic Plateau Region, LUC class VI was not mapped above approx. 900 m a.s.l.

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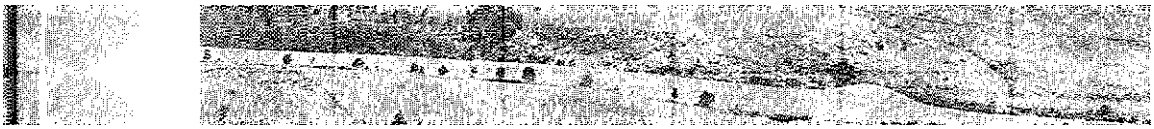

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, Fig. 74: LUC subsuite 7e: General view of southeastern Hauhungaroa Range, showing relationship between LUC subsuites 7c and 7e. Hills in middle of photo are mainly VIe9 (LUC subsuite 7c). VIIe6 on steep slopes behind, and VIlcl on crest of range. Steep forested land in right j background is predominantly Vile 11 on Upper Tertiary sandstones (LUC subsuite 8b). j Foreground is mainly Taupo flow tephra (LUC subsuite 7f). Kuratau district, N102/183145 1 looking W.

Fig- 75: 1.1 C subsuite 7e: VIIe6 on small rhyolite dome (Pohaturoa). Atiamuri, N85/488734 looking SSW.

Fig. 76; LUC subsuite **7e:** VIIe7 on deep Oruanui Breccia over **andesite. Subject to severe sheet erosion under pasture. In foreground is IVel3 (LUC subsuite 7g). Kuratau, N102/172143** looking **E.**

mwm

Fig. 77; LUC subsuite 7e: VIel and VIIcl **on** crest **of Hauhungaroa Range, with VIs2 (LUC subsuite** 7c) **in front; these 3 LUC units separated according to altitude. Vllel2 on Taupo flow tephra (LUC subsuite** 7f) **in foreground. Whanganui catchment, south of Te Hiapo, N102/070240 looking** S.

LUC SUITE 7f: TAUPO FLOW TEPHRA AND WATER-SORTED TEPHRA

General

This subsuite occurs on Taupo flow tephra (also known as Taupo breccia or Taupo ignimbrite) and on Taupo water-sorted tephra (Taupo volcanic alluvium). The flow tephra is the deposit of the ***nuees ardentes*** (glowing avalanches) which formed part of the Taupo eruptions. These flowed rapidly over the land surface and infilled lower-lying areas to leave a poorly-sorted breccia of ash, lapilli and block texture. Taupo water-sorted tephra is the result of subsequent redeposition of Taupo Pumice materials through alluvial, lacustrine and, to a lesser extent, colluvial processes (Rijkse 1974).

These two types of Taupo deposits were not separated in the NZLRI, partly because of the difficulty of field recognition in many areas, and partly because frequent overlapping of the two deposits gives little purpose to separation at the scale of mapping. Thus several LUC units contain both flow and water-sorted tephra. To some extent, deposits close to source are more likely to be flow tephra, while deposits further from source are more likely to be water-sorted, but there are many exceptions to this generalisation. However, when assessing land use capability, it was useful to subdivide the deposits according to the dominant texture of the upper members. These tend to be coarser towards source and finer away from source. Soils derived from the coarser materials have poor structure, are more droughty and have less profile development. This affects productivity and susceptibility to erosion, especially under arable use. Therefore, texture has been used as the basis for separation of the arable LUC units. However, because this criterion is not as significant for the non-arable LUC units, they have not been separated in this way. Also included in this subsuite are two LUC units where flow tephra occurs in poorly drained areas.

The subsuite occurs throughout the area of the Taupo Pumice LUC suite (Fig. 55). It is most extensive around and to the north of Lake Taupo, where it is frequently mapped in combination with LUC subsuite 7d. There are very extensive areas east of Lake Taupo, and small outliers in the Whirinaki Valley near Minginui and the Whakatane Valley at Ruatahuna. There are also large areas to the south around Lake Rotoaira and on the Rangipo Desert. The subsuite extends to the north as far as the south-west fringes of the Mamaku Plateau and the Kapenga Swamp, and to the west as far as the Benneydale district. Taupo flow tephra and water-sorted tephra also occur widely outside the regional boundary.

This is the most widely distributed subsuite in the Taupo Pumice LUC suite. It covers an area of 154,850 ha, 19% of the Taupo Pumice LUC suite and 8.7% of the total area of the region. There are 11 LUC units: 3 on arable areas with finer-textured soils (IllelO, IIIs6 and IVel5); 3 on arable areas with coarser-textured soils (IVs4, Illel2 and IVel8); and 5 on non-arable areas (VIe24, Vile 12 and VIIIe2, with VIw2 and VIIIw2 in swampy areas). For convenience, the fine-textured arable together with the swampy LUC units, and the coarse-textured arable and the non-arable LUC units have been grouped in Tables 27a and b respectively.

It is again emphasised (see p. 117) that it is not only very difficult to separate flow tephra and water-sorted tephra from each other, but also to separate these two from airfall tephra. Therefore, there are significant inclusions of areas of airfall Taupo Pumice in most LUC units in the subsuite. The subsuite has also been widely mapped in conjunction with map units from other LUC suites and subsuites, especially with LUC subsuites 7d, 7g, 7h and 7i in the Taupo Pumice LUC suite, with LUC suite 3 on alluvium, and with LUC subsuites 6c on Ngauruhoe ash and 8c on ignimbrite.

Climate

The climate most typical of this subsuite is that around Lake Taupo and the upper Waikato Valley. Representative climate stations are Taupo, Turangi and Atiamuri. The most important climatic factor is the summer soil water deficits arising from high temperatures and low rainfall. Intense localised rainstorms, occurring at any time of the year, often initiate gully erosion. Elsewhere, the climate varies considerably from that at Taupo, being moister (e.g.,

in the King Country), cooler (e.g., Kaingaroa, Upper Rangitaiki), or both (e.g., Kaimanawa Range).

Physiography

In the vicinity of the Taupo Volcanic Centre, Taupo flow tephra has itself contributed to the shaping of the present-day landscape, forming extensive relatively flat areas around Taupo Borough, the Broadlands district, the upper Rangitaiki Plains, Turangi and Lake Rotoaira. Slightly further away from source, flow tephra or water-sorted tephra has infilled large valley systems and basins, e.g., Moerangi and Reporoa Basins, the Ngakuru Graben, and the Waikato, Whirinaki, Hinemaiaia, Waipakihi and many other sizeable river valleys. These enclosed areas, operating as cold air sinks from surrounding hills or rolling lands, are known as 'frost flats'. In many of them the water-courses have cut down through the Taupo flow tephra to expose underlying rocks. Almost all land in this subsuite is flat to rolling, although more than half was recorded as having dissected or compound slopes. There are many ephemeral waterways on these surfaces.

The Taupo eruption had such energy that flow tephra overtopped large massifs around the Taupo Volcanic Centre, such as the Kaingaroa Plateau and Hauhungaroa Range, where it remains as a surficial layer or in small pockets. On the southern Kaingaroa Plateau, eastern Taupo district and upper Rangitaiki Plains, Taupo flow tephra is present at varying thicknesses, but other factors such as underlying lithology and climate have also had an important influence on land use capability. This has given rise to a complex association of this subsuite with LUC subsuites 7h and 7i.

Rock Type and Soil Parent Material

Taupo flow tephra or water-sorted tephra, both mapped as Tp, were the only recorded rock types over about 70% of the subsuite. Tp overlying or associated with other rock types was recorded over the remaining area. A wide range of underlying or associated rock types was recorded, the most common being Oruanui Breccia (Ft). The most common associated tephras were Taupo airfall tephra or older 'Mo' tephras, but on small areas thin Ngauruhoe or Rotomahana ashes also influence soil development.

Soils

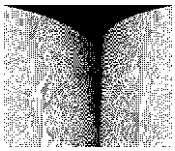
Nearly 75% of the subsuite was mapped using soils from the Taupo Survey. Most of the remainder was mapped using soils from the King Country, Waiotapu and General Surveys, and very small areas were covered by the Whakatane and Rotorua Surveys. Nearly 90% of the subsuite had yellow-brown pumice soils recorded, occasionally podzolised. About 12% of the subsuite has a thin mantle of Ngauruhoe ash (Turangi, Kuratau series) but the resulting soils were still classified as yellow-brown pumice soils.

Yellow-brown pumice soils derived from flow or water-sorted tephra differ from other yellow-brown pumice soils because of their compact sub-soils and the unsorted nature of the parent material (flow tephras only). There is a wide variation in the texture, properties and fertility of the soils derived from both flow and water-sorted tephra (see p. 153).

Most of the remaining soils occur on peaty areas or areas of present peat accumulation. These are classified as recent soils from alluvium, gley, or organic soils (e.g., Tokaanu, Hinemaiaia series). They occur on LUC units with a wetness limitation which are very similar to those in the alluvial LUC suite (see p. 50). They have been included in this subsuite because, if drained, their soils would retain similar properties to other soils derived from Taupo flow tephra, in particular the same erosion problems. The remaining soils are steepland soils related to podzolised yellow-brown pumice soils, occurring on steeply dissected land south of Lake Taupo.

Erosion

Slight erosion was recorded on map units covering 32% of the subsuite, moderate erosion on map units covering 11%, and severe erosion on 1%. The most significant erosion type was gully erosion, which affected map units covering 30% of the area or 65% of the area where erosion was recorded. It was by far the most important erosion type at severities



greater than slight. Gully erosion is very significant in Taupo flow tephra because the physical properties of this deposit allows rapid headward migration and enlargement of gullies once they are initiated (see p. 118 for references). Streambank erosion is often associated with the gullying process and is recorded in map units covering 12% of the area, but usually only at slight severity. Sheet erosion was recorded on map units covering 10% of the subsuite. Minor forms of erosion recorded include rill, wind, and soil slip, the last occurring only on deeply dissected areas. Potential erosion assessed on Taupo flow and water-sorted tephra ranges from moderate to extreme and is mainly assessed as association R.

Land Use and Land Management

The most important present land use is exotic forestry, which covers over 40% of the subsuite, mainly east of Lake Taupo. Pastoral use covers about 35%, being mainly sheep and cattle grazing, with dairying on small areas of the best land. Pastoral use requires supplementary winter fodder cropping, while lucerne cropping is important in the area north of Taupo, both as supplementary feed and as a cash crop.

The remaining land is undeveloped. About 6% of the subsuite is occupied by manuka or ***Dracophyllum*** dominated heathland vegetation which formerly covered most of the subsuite. The remainder is occupied by small areas of beech forest, short tussock associations, wetland associations or exotic scrubweeds such as broom and gorse.

A significant potential for diversification exists only on the three arable LUC units which have fine-textured soils, and even here, only with the provision of irrigation. On all arable LUC units intensification of pastoral use is possible because present stocking levels are low to medium. But pastoral use is severely limited by summer drought and winter frosts, and grass grub infestation, as well as by the poor natural fertility, trace element deficiencies and erodibility of the soils. The non-arable LUC units, except for parts of VIe24, are generally unsuitable for pastoral use.

Exotic forestry is the most suitable land use on much of the subsuite, except for those areas with a wetness limitation. However, site indices are not as high as on most other Taupo Pumice subsuites due to their compact and coarse-textured subsoils, and high water tables in areas adjacent to rivers. An expansion of exotic forest on up to about two-thirds of the subsuite area is recommended in NWASCO (1982).

Soil conservation measures are mainly aimed at gully control and prevention. They include retirement of gullies and permanent waterways, construction of flumes to carry stream flows across gully heads, planting or strengthening of gully heads and gully sides liable to streambank erosion, and maintenance of cover on ephemeral waterways. Contour cultivation and establishment of shelter are recommended on arable land. Exotic forest management should comply with the "Forest Operations" guidelines (NWASCO 1976). Small areas of LUC class VIII land unsuitable for development are associated with waterways in all LUC units in the subsuite.

Scenic and ecological reserves are located around Lake Taupo, on small wetland areas and in the Whirinaki State Forest Park. This subsuite also contains remnants of rare habitats such as wetlands, heathland and short tussock communities, especially on the Upper Rangitaiki Plains.

LUC Units on Taupo Flow Tephra and Water-Sorted Tephra (Tables 27a, b)

LUC unit IllelO (6,100 **ha)—**Figures 69, 80

This LUC unit occurs on undulating, slightly dissected surfaces with fine-textured soils. It is distributed mainly along the Waikato River between Mihi and Atiamuri, and in the Reporoa Basin. Small areas occur in the King Country. Atiamuri sandy silt, the most extensive soil, is the finest-textured soil derived from Taupo flow tephra. It retains moisture fairly well and is used intensively for dairying. Whenuaroa and Hinemaiaia soils are slightly coarser-textured. IllelO is the highest-ranked LUC unit in the subsuite because it has a potential for diversified arable use, provided that correct fertiliser applications and soil conservation measures

are applied. It has a moderately high pastoral potential and medium to high exotic forestry potential. It is already highly developed.

TABLE 27a: LUC units on Taupo flow tephra and water-sorted tephra
a) fine-textured and peaty soils.

LUC UNIT	IIIs6	Hie 10	IVe15	Vlw2	VIIIw2
RELATED LUC UNIT (LUC Suite)	IVs4 (7f)		IVe7 (7d)	VIIel2 [1] (7f)	
PHYSIOGRAPHY	Major river valley	Low river terrace (post-Taupo surface)	Higher river terrace (pre-Taupo)	Low river terrace (post-Taupo)	
			Accumulating swamps in river valleys or lake margins		
	16 800	6 100	5 800	1 750	1 450
AREA (ha)					
SLOPES	A B A'	B B + C A'	B' B' + C C	A B	A
SOILS		Whenuaroa	Taupo Turangi Atiamuri Whenuaroa Hinemaiaia	Atiamuri Waipahihi Kaingaroa Mokai Mangorewa	Puaroa Tokaanu Mokai
% MAP UNITS CONTAINING EROSION	lSb,W	Sheep & cattle Exotic forestry Dairying	Sheep & cattle Undeveloped Exotic forestry	Undeveloped Extensive grazing	16
PRESENT EROSION	!Sb(lSb,W)		0		lSb
POTENTIAL EROSION	Sheep & cattle Dairying Lucerne cropping Exotic forestry l-2G,lSb,Sh	l-2G,lSb,Sh	0		Undeveloped
PRESENT LAND USE	ISh,lSb,Sh (2G,Sh,R,lSb)	3G,Sh,R,lSb	2G,Sb		
20					

STOCK CARRYING CAPACITY (s.u./ha)	11, 15, 18*	0
SITE INDEX (m)	27-35 14, 18, 20* 27-35 9, 12, IE 28-35 ■, -, 10	

TABLE **27b: LUC units on Taupo flow tephra and water-sorted tephra**
b) coarse soils.

LUC UNIT	IVs4	IIIe 12	IVe18	VIe24	IVe18	VIIe12	VIIIe2
RELATED LUC UNIT (LUC Suite)		|IVe7 |(7d) etc VIIel2		(7f)| | I '			
PHYSIOGRAPHY	Low river terrace (post-Taupo)	|Higher iriver 'terrace Kpre-iTaupo)	Deeply dissected post-Taupo surface	Dissected post-| Taupo surface			
Major river valley and lake margins		VIe2 4 l(7f) | and					
		Post-Taupo. surface on' ignimbritel plateau (above 600 m a.s.1.)					
AREA (ha)	9 350	6 350	11, 11, 18*	Exotic forestry	2- 3G,Sh,Sb; 2R	c. 15	Taupo
SLOPES	A B	B B' B + C	29-34	Sheep, cattle Undeveloped	Exotic forestry Extensive grazing Undeveloped	1Sh,Sb	Waipahihi Atiamuri
SOILS	Whenuaroa Hinemaiaia Poronui	Waipahihi Kaingaroa	42 950t B [1] B B + C	11, 11, 15t		1Sh,G (2G,Sh,W,Sb)	93
% MAP UNITS CONTAINING EROSION	22	19	Waipahihi Kaingaroa Rangipo	25-29+ 35 950	9, 9, 12	Exotic forestry Undeveloped	1-2G,Sb; ISh 3G,Sb; 2Sh
PRESENT EROSION	1Sb	1G,Sh		B ' C B' + C	25-34 42 950+	Extensive grazing	Extensive grazing Exotic forest Undeveloped
POTENTIAL EROSION	1G,W,Sb (2G,W; 1Sb)	1Sh,G (2G,Sh,R)	c.50 1-2G; 1Sh,Sb	Kaingaroa Taupo Waipahihi Otamatea	B' B + A B + C	11, 11, 15+ 25-29+ 14 300	10, 10, 12 25-34 14 050
PRESENT LAND USE	Sheep, cattle Undeveloped Exotic forestry	Sheep, cattle Exotic forestry Dairying	1-2Sh,G (3G,Sh,R; 2W,Sb)	72 1- 2G,Sh; 1Sb	Kaingaroa Otamatea	B [1] C ' A + G	G + A
STOCK CARRYING CAPACITY (s.u./ha)	12, 14, 17 30-32						

Pihanga Poronui Otamatea	1-2G,Sb;!Sh,sSl 5G: 4Sb,Sh	Undeveloped Extensive grazing	0

+Applies to whole LUC unit (see IVe18 in other column)

LUC **unit IIIel2 (6,350 ha)—**Figure 81

This LUC unit differs from IllelO chiefly by its significantly coarser-textured, excessively drained soils. It is scattered through the Taupo and Oruanui districts, and also occurs north of Mt Tauhara and to the south-west of Lake Taupo up to an altitude of 650 m a.s.l. I_n the latter district the soils have a thin mantle of Ngauruhoe ash. Most areas occur on sheet-washed Taupo Pumice and dry out badly in summer.

Illel2 shows a fairly similar land use pattern to that on IllelO, although it is used less for dairying. It has a slightly lower pastoral potential but a similar exotic forestry potential. There is considerable potential for intensification of pastoral use because some areas have been recently developed and are not yet highly productive.

LUC **unit IIIs6 (16,800 ha)—**Figures 78, 79, 103

This LUC unit occurs on extensive, flat to undulating terraces formed mainly on Taupo Pumice alluvium. The two largest areas are in the Broadlands district and along the Tongariro River Valley south of Turangi. It is also scattered through the Reporoa-Ngakuru-Atiamuri district, western Taupo and the King Country, and as far east as Minginui and Ruatahuna.

In the Broadlands district, IIIs6 occurs on extensive terraces which were formerly the bed of a lake formed by the blocking of the Waikato River. Elsewhere it occurs on both flow tephra and colluvium, which south of Turangi is mantled with Ngauruhoe ash (Turangi series). The parent materials of the dominant soils (Whenuaroa series*) have a wide range of particle size, with the result that soils of this LUC unit are variable in texture. In future remapping IIIs6 may be split into two LUC units, one for the coarser soils nearer Lake Taupo and the other for finer soils further away from source. The latter would correlate with LUC units on Taupo Pumice alluvium in the Waikato and Taranaki-Manawatu Regions.

IIIs6 is mainly used for sheep and cattle farming and for dairying. Exotic forestry is a minor present land use but has a generally high potential. IIIs6 is only moderately suitable for arable use, which at present is restricted to minor winter fodder cropping. However, lucerne is of major importance in providing supplementary feed when pasture production is lowered due to summer water deficits; in the Broadlands district it is also grown as a cash crop. Soil conservation measures aimed at provision of shelter and prevention of gully and streambank erosion are important in achieving the potential productivity of this LUC unit.

LUC **unit IVs4 (9,350 ha)—**Figure 78

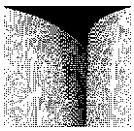
This LUC unit occurs on flat to gently undulating low terraces and lake margins, chiefly around Lake Taupo and on the upper Waikato River. It also occurs at Minginui. Most of these areas receive less than 1300 mm rainfall annually and severe summer drought is the main limitation to use. There is also a potential for moderate erosion under arable use. IVs4 generally occurs on lower and more recent terraces than IIIs6 and has coarser-textured and more infertile soils derived from unsorted redeposited tephra. The dominant soil series (Whenuaroa) is the same as for IIIs6, but in IVs4 it occurs in a coarse gravelly phase, resulting in severe limitations to arable use. Soils derived from resorted Taupo tephras, e.g., Hinemaiaia and Tokaanu series, are also coarse-textured and poorly sorted. There are small wetland inclusions.

Present land use is dominated by extensive grazing, with sheep and cattle farming occurringon about 60% of the area. Nearly 25% is undeveloped, while exotic forestry is a relatively minor land use. NWASCO (1982) recommends development mainly for pastoral use, although exotic forestry also has a high potential.

LUC **unit IVel5 (5,800 ha)—**Figure 82

This LUC unit occurs on dissected, undulating to gently rolling slopes with fine-textured soils. It has a very scattered distribution; the largest areas occur close to the Waikato River between Mihi and Whakamaru, while other areas are scattered in the Reporoa-Waikite-Ngakuru district, the King Country, and the 'frost flats' on the mid Whaeo River. IVel5 is often finely dissected and has many ephemeral waterways and dry gullies.

***The soils in the Broadlands district as mapped in the General Survey are recorded as Taupo set, but are in fact dominantly Whenuaroa series (W.C. Rijkse, pers. comm.).**



Pastoral land uses, including minor areas of dairying, occupy about 60% of the area, exotic forestry about 20%, and the remainder is undeveloped. Pastoral potential is moderately high but present use is only at low stocking rates so that there is scope for considerable intensification. Because of a severe erosion potential under cultivation, IVel5 is not suitable for arable use except for small areas of occasional supplementary feed cropping. Most presently undeveloped areas occur in predominantly exotic forest districts and development to that use is recommended by NWASCO (1982).

LUC unit IVel8 (42,950 ha)—Figures 83, 88

This LUC unit occurs on dissected undulating surfaces with coarsely-textured soils, which have a potential for severe erosion under arable use. It is the most extensive LUC unit in the subsuite, occurring in low-lying areas around Lake Taupo (especially the Kinloch and Kuratau areas), scattered areas to the north-west of Lake Taupo and in a large area extending east from Lake Taupo to the upper Rangitaiki catchment and southern Kaingaroa Plateau, IVel8 has been mapped in two situations which may be separated in future remapping, It was originally thought of as a more dissected version of IIIel2 and IVs4, chiefly in the Taupo Volcanic Centre, and was described in this context in the regional extended legend, However, in the eastern Taupo district it was also mapped at higher altitudes (up to 800 m a.s.l. on the Kaingaroa Plateau), where the upper Taupo Pumice tephra flow member is widespread (Pullar 1980). These two situations are shown separately in Table 27 because, although they form a continuum, their different physiographic position affects the soils, microclimate and erosion pattern.

Soils are variable but have common properties of coarse texture, low fertility and susceptibility to drought. Most of IVel8 has little present erosion but there is a moderate to severe potential under arable use (the elevated areas are slightly less dissected and have a slightly lower potential for gully erosion). Because of climatic, soil and erosion factors IVel8 is not suitable for arable use except for occasional winter fodder cropping, as part of a pasture renewal programme.

Present land use is dominated by exotic forestry, which occupies about 60% of the area, undeveloped land covers just under 20%, and the remainder is used for extensive grazing, Although the potential for both pastoral and exotic forestry use is given as medium (higher on some Kaingaroa and Otamatea soil phases), NWASCO (1982) has recommended a dominantly exotic forestry use because of location, present land use and erosion potential. Small areas of cutover beech forest within the Kaimanawa State Forest Park are zoned for long-term indigenous management.

LUC unit VIe24 (35,950 ha)—Figures 85, 87

This LUC unit occurs on dissected, undulating to rolling land on which the degree of dissection and erosion potential precludes arable use. VIe24 is even more widespread than IVel8, occurring in the same areas as the latter as well as in valleys and depressions to the north and west of Lake Taupo. Like IVel8, it has very varied soils, some with finer texture, and includes minor areas of Taupo airfall tephra (where Taupo eroded complex soils are mapped). The physiographic variation discussed above for IVel8 applies also to VIe24 but to a lesser extent.

Slight gully and sheet erosion is very extensive on both pastoral and exotic forest land, although moderate erosion is more prevalent on pastoral land. Development of VIe24 for pastoral use, for which it has only a medium potential, is subject to the application of intensive soil conservation measures. Therefore, exotic forest is recommended as the main land use, although its potential is variable. Forestry management should conform to the Forest Operations" guidelines (NWASCO 1976). Most of the undeveloped land in VIe24 occurring east of Lake Taupo is at present being converted to forestry use.

LUC unit VIw2 (1**,750 ha)—**Figure 84

This LUC unit occurs on low-lying areas of water-sorted tephra which have a very high water table and experience frequent flooding. It has a scattered distribution, mainly in the southern Rotorua district, and around Lake Taupo. It has sometimes been mapped in areas where tephric alluvium was not derived from Taupo Pumice, e.g., around the Ohau Channel between Lakes Rotorua and Rotoiti. However, these areas were included in VIw2 because VIwl (LUC suite 3) was restricted to coastal areas. VIw2 has mainly organic soils formed on peat and colluvial Taupo Pumice. It is mostly undeveloped, its vegetation cover being mainly wetland associations, with minor grassland or scrub. It has been classified as LUC class VI because it can be drained, and some grazing can be carried out in summer. However, such drainage would probably not be justified in terms of cost, erosion potential when drained, scattered and local distribution of the LUC unit, and habitat conservation values.

LUC unit Vile 12 (14,300 ha)—Figures 77, 86, 87

This LUC unit is similar to VIe24 but is more deeply dissected and has a greater erosion potential, especially for gully erosion. It has a similar scattered distribution to VIe24 but is not as extensive. It was mapped mainly around Lake Taupo, along the eastern Reporoa Basin and in the Ngakuru Valley. It usually occurs as a comparatively narrow strip in the bottoms of river valleys, or on low terraces, but may form extensive areas where the relief is gentle, e.g., in the Pueto catchment east of Mount Tauhara.

Almost all of Vile 12 is affected by gully, streambank or sheet erosion. Erosion control is difficult because of the dissection pattern and the problems in controlling runoff from higher ground. Vile 12 occurs most widely in low rainfall areas which are susceptible to summer drought and severe grass grub infestations and where pasture production is low. For these reasons it is not recommended for pastoral use although extensive grazing presently occupies nearly 50% its area. Only about 30% is at present used for exotic forestry but because the potential is medium to high it is recommended (NWASCO 1982) that this should be its predominant use. Forestry management should conform to the "Forest Operations" guidelines (NWASCO 1976).

LUC unit VIIIe2 (14,050 ha)—Figure 88

This LUC unit occurs mainly along stream channels and ephemeral water-courses that have a very severe to extreme potential for gully, streambank and sheet erosion. It is very scattered, occurring in most of the major river valleys flowing into Lake Taupo, and in the upper Rangitaiki catchment. The main differences between VIIIe2 and Vile 12 are that on the former the proportion of very steep slopes is greater and that steepland soils (Pihanga series) have been widely mapped south of Lake Taupo. Elsewhere, the soils recorded are the same as in the rest of the subsuite. VIIIe2 also contrasts with Vile 12 and VIe24 in its vegetative cover and its degree of erosion. It has a mainly woody vegetation cover which is dominated by beech forest and indigenous scrub species, especially ***Leptospermum.*** Land uses other than catchment protection are confined to minor extensive grazing and exotic forest at the margins. VIIIe2 is therefore less affected by present erosion than is Vile 12 or VIe24, but because of its severe erosion potential catchment protection is recommended.

LUC unit VIIIw2 (1,450 ha)—Figure 89

This LUC unit consists of perched swamps on Taupo flow or water-sorted tephra, with extreme limitations to use. It occurs in the southern and western Taupo districts and on the upper Rangitaiki Plains. Most soils are organic. VIIIw2 has not been recorded in swamps on the margins of Lake Taupo itself, e.g., at Turangi, because these are areas of accumulation and have therefore been included in LUC suite 3.

Recorded inventory factors on VIIIw2 are similar to those of VIw2. It is wholly undeveloped, the main vegetation being wetland associations dominated by flax. Like VIw2, VIIIw2 could be drained in most cases, but it is considered that if this were done, drains would incise the flow tephra to form large gullies with a potential for further extreme gully erosion. These swamps are therefore not recommended for development.

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s 4

78:LUC subsuite- 7f: IVs4 on lower terraces, and IIIs6 on mid terraces of Waikato River. Hills in background are predominantly VIelO (LUC subsuite 7c) and VIIe7 (LUC subsuite 7e). Whakamaru district, N84/433704 looking NW.

wiktsmtmams

Tig. 79: LLC subsuite 7f: IIIs6 in Broadlands Basin, showing lucerne cultivation. Rotokawa district, N94/728465 looking S.

Sig n

Fig. 80: **LUC subsuite 7f: IllelO. Compare fine soil texture to that shown in Figs. 79 and 86. Waikite Valley, N85/727788 looking NE.**

Fig. 81: **LUC subsuite 7f: IIIel2 on coarse-textured Taupo flow tephra near Lake Taupo. Hills in background predominantly VIe9 and Vie 10 (both LUC subsuite 7c). Kinloch district, N93/413430 looking WSW.**

82: **LUC subsuite *If:* IVel5 on fine-textured Taupo flow tephra. Hills behind are VIe5, with IVe4 on tops (both LUC subsuite 7a). Earthquake Flat district, N76/748918 looking SE.**

83: **LUC subsuite *If:* IVel8 on Kaingaroa Plateau, under pastoral use in a firebreak. VIe22 (LUC subsuite 7i) behind. Low Level Rd, Kaingaroa Forest, N95/992513 looking N.**

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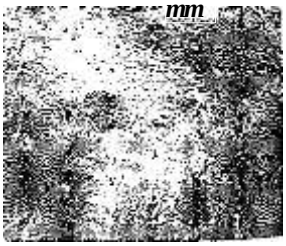
Fig. 84: LUC subsuite 7f: VIw2 on water-sorted Taupo tephra near Lake Taupo. VIIIwl (LUC suite 3) behind. Hill in background is VIe9 (LUC subsuite 7c) on rhyolite. Waiotaka Rd, Turangi district, N102/342045 looking NNW.

Fig. 85: LUC subsuite 7f: VIe24 on coarse Taupo flow tephra in an undeveloped 'frost flat'. Hills behind are mainly VIIe7 (LUC subsuite 7e). Hingapo Rd, East Taupo district, looking N.



;: I.l'C subsuite 7f: VIIel2 on very coarse Taupo flow tephra. Forest establishment improved by furrowing to permit cold-air drainage. Maroa district, N85/533682 looking N.

Fig. 87: **LUC subsuite 7f: VIe24 (foreground) and Vile 12 (in gully) under pastoral use. Hill behind is VIIe7 (LUC subsuite 7e) on Huka sediments mantled with deep Taupo Pumice. Kinloch district, N93/432439 looking S.**

Fig. **88: LUC subsuite** 7f: **VIIIe2 in very deep Taupo flow tephra close to source. Flat land at top of opposite bank is IVel8. Waitahanui River, N103/591180 looking NW.**

Fig. **89: LUC subsuite 7f: VIIIw2 in swamp on redeposited Taupo Pumice. Hills behind are mainly VIe5 (LUC subsuite 7a) and Vllel (LUC subsuite 4a). Kapenga Swamp, N76/700718 looking**

LUC SUITE 7g: COMPLEXES OF TAUPO TEPHRAS

General

This subsuite is characterised by complexes of Taupo airfall and flow or water-sorted tephras. Although, as has been emphasised previously, most subsuites of the Taupo Pumice LUC suite contain more than one type of tephra in their soil parent material, one type is usually dominant. In this subsuite, however, the airfall and non-airfall tephras are equally important and very closely associated. At a detailed mapping scale, the LUC units would be split into relevant airfall, flow or water-sorted LUC units (LUC subsuites 7c, 7d, *If).* However, at the scale of the NZLRI this separation was not possible; indeed, when viewed at this mapping scale, the complexes of this subsuite comprise a distinctive landscape of moderate relief, dissected but not sharply so.

The subsuite has a scattered distribution similar to that of LUC subsuite 7f. Its most extensive occurrence is in the western Taupo district, from Whakamaru south to Moerangi Station. It also occurs in the southern Rotorua-Taupo district, in the mid Tauranga-Taupo catchment, around Lake Rotoaira, and on the eastern margin of the upper Rangitaiki Plains.

The area of the subsuite is 32,500 ha, 4% of the Taupo LUC suite and 1.8% of the total area of the region. There are only three LUC units: IVel3, IVel4 and VIel9. IVel3 and IVel4 are differentiated according to soil texture (cf. LUC subsuite *If).* Within the main areas of the subsuite are inclusions of all LUC units of the related Taupo Pumice subsuites, (7c, 7d and *If).*

Climate

The climate of the LUC suite as a whole shows a similar range to that on LUC subsuite 7f, but IVel3 and Vie 19, the two most extensive LUC units, do not occur widely in areas where annual rainfall is less than 1300 mm. Thus most of the subsuite has a higher and more constant rainfall than does LUC subsuite 7f. Turangi and Otutira are representative climate stations.

Physiography

In the west, the subsuite occurs in areas of moderate relief on the west Taupo ignimbrite sheets. Other areas occur in various physiographic zones, mainly between 450-600 m a.s.l. but rising to 900 m a.s.l. in the Upper Rangitaiki Plains. More important, however, is the detailed physiographic pattern, which is invariably one of dissected land of moderate relief, with flow, water-sorted or colluvial tephra filling in the depressions, giving a hummocky appearance to the landscape. 90% of the area is predominantly undulating to strongly rolling, but there are many complex slopes.

Rock Type and Soil Parent Material

The rock type over most of the subsuite was normally recorded as Taupo ashes over 'Mo' ashes, plus Taupo flow or water-sorted tephra. The underlying rock type was not usually recorded, but is usually ignimbrite or, more rarely, pumice breccia or lahar.

In some situations where water-sorted or colluvial Taupo tephras were scattered in many small areas, they were not recorded in the rock type inventory; only airfall tephras over the underlying lithology being recorded. In these cases only a soil derived from air fall tephra was recorded, although more than one soil phase would certainly be present. This occurred mainly in the Oruanui district. Here, LUC units from this subsuite were used to indicate the distinctive dissected hummocky nature of the landscape.

Soils

67% of the area of the subsuite was mapped using soils from the Taupo Survey. Most of the remainder was mapped using soils from the King Country Survey, with very small areas from the Rotorua and Waiotapu Surveys. Nearly 90% of the soils recorded were yellow-brown pumice soils. For most map units a complex of soils derived from both airfall and flow or water-sorted tephras was recorded, except- for the areas noted above. Soils from airfall tephra, e.g., Tihoi, Oruanui or Rangipo series, were more often the first soil recorded.

If soils from flow or water-sorted tephras were clearly dominant, the area was usually mapped in LUC subsuite *If*.

Soils other than yellow-brown pumice soils included composite yellow-brown pumice soils on yellow-brown loams, or yellow-brown loams (e.g., Maroa or Ngakuru series). These were recorded in the northern areas on steeper slopes where Taupo ash was thinner (see VIel9). Shallow Ngauruhoe ash was present as a soil parent material over about 20% of the area (e.g., Turangi, Rangipo, Kuratau series). A significant feature of this subsuite, resulting from the relatively high rainfall, is that one-third of the soils are classified as podzolised, and most soils apart from Taupo series (IVel4) are moderately to strongly leached. This, together with compacted subsoils in the areas of flow tephra, is a cause of the very variable exotic forest site indices on this subsuite.

Erosion

Slight erosion was recorded on map units covering 47% of the subsuite and moderate erosion on map units covering 4%. The fact that this subsuite tends to be dominated by the airfall Taupo component rather than non-airfall tephras is indicated by the fact that sheet erosion was more extensively recorded than gully erosion. However, gully erosion was slightly more important than sheet erosion at moderate severity. Streambank, rill and tunnel gully erosion was recorded occasionally. Potential erosion is assessed as slight to severe, and is classified in erosion associations P and R on the airfall and non-airfall components respectively.

Land Use and Land Management

Present land use is dominated by sheep and cattle rearing, which occupies about 50% of the subsuite. Supplementary winter fodder cropping is widespread. Exotic forest occupies about 17% of the area and the remainder is undeveloped. The largest area of undeveloped land is beech forest in the Tauranga-Taupo catchment. Minor indigenous scrub occurs within pastoral areas.

Land in this subsuite has a rather variable potential. Pastoral potential is medium to moderately high, but significant arable potential is very restricted and no diversification beyond the present supplementary winter fodder cropping is envisaged. The most serious erosion hazard is gully erosion in the waterways and dissected areas, and for this reason recommended soil conservation measures are aimed at maintaining vegetative cover in these areas to prevent gully initiation.

Exotic forestry potential is very variable due to climatic and soil factors already mentioned but it is likely that exotic forestry will increase. NWASCO (1982) recommends that its proportion increase to nearly 60% of the subsuite; however, this calculation is based on a conservative potential stock carrying capability and optimal exotic forestry potential for Vie 19 (see below). Also, most of the existing indigenous forest in this subsuite occurs within the Kaimanawa State Forest Park and is zoned for protection under the present management plan.

LUC Units on Taupo Tephra Complexes (Table 28)

LUC unit IVel3 (18,000 ha)—Figures 76, 90

This LUC unit comprises complexes of rolling slopes mantled with airfall tephra, and intervening valleys filled with finely textured Taupo flow tephra. It is the most extensive LUC unit in the subsuite. Its main occurrences are in the King Country, the Whakamaru- western Taupo district, the Tauranga-Taupo catchment and around Lake Rotoaira. Rainfall is relatively high and most of the soils are moderately to strongly leached. Ngauruhoe ash, although not thick enough to be recorded in the rock type inventory, is a soil parent material in southern areas. Present erosion is minor although potential erosion under cultivation is assessed as severe.

The dominant land use is sheep and cattle farming, which occupies a little over 40% of the area. Pastoral use on IVel3 has a moderately high potential. Supplementary root and fodder cropping is widespread in pastoral areas but other arable uses are not recommended. Exotic forestry is a minor land use, occurring on less than 20% of the area. Forestry site indices are very variable and not all undeveloped land is suitable for exotic forestry use which was recommended by NWASCO (1982).

LUC unit IVel4 (1,400 ha)—Figure 91

This LUC unit comprises complexes of dissected, undulating and rolling slopes with coarse-textured soils. It was mapped only to the east of Taupo township, and in the Rangiatea Land Development Block in the western Taupo district. These areas receive less than 1300 mm rainfall annually, IVel4 thus contrasting with IVel3 in climate as well as soil texture. Most of the soils recorded are Taupo eroded complex soils. Both gully and sheet erosion are much more widespread than on IVel3, and the erosion potential is similar to that on IVel8 (LUC subsuite *If)* which IVel4 is similar to and often associated with. Arable use other than occasional supplementary fodder cropping is not recommended.

Extensive grazing is the only present land use on IVel4, but application of soil conservation measures (as for IVel8) and careful management are required if potential grazing levels are to be achieved. Exotic forestry potential is generally high, and would be a suitable alternative land use.

LUC unit Vie 19 (13,100 ha)—Figures 90, 91, 92

This LUC unit comprises complexes of strongly rolling hills and intervening infilled valleys. It is a hill country equivalent of IVel3 and has a similar distribution to the latter although it is more extensive north-west of Lake Taupo and does not occur south of Lake Taupo. In many instances the basins and valleys in Vie 19 are infilled with colluvial Taupo

TABLE 28: LUC units on complexes of Taupo tephras.

LUC UNIT	IVe14	IVe13	Vle19
RELATED LUC UNIT (LUC Suite)	IVe7 (7d) ,IIIel2 *ha* Illel0 (7f) IIVe8 (7c)		VIe24 (7f) VIe9
AREA (ha)	1 400	18 000	13 100
SLOPES	Taupo	Tihoi Rangipo Oruanui Otamatea	D D + E Waipahihi Tihoi
SOILS	71	33	79
% MAP UNITS CONTAINING EROSION	1G,Sh	1G,Sh	1-2G; 1Sh,Sb,T
PRESENT EROSION	1Sh,G(3G,Sh,R)	1Sh,G(3Sh,R,G)	2G,Sh,Sb,T
POTENTIAL EROSION	Grazing Undeveloped	Sheep & cattle Undeveloped Exotic forestry	Sheep & cattle Exotic forestry Undeveloped
PRESENT LAND USE		Oruanui Ngakuru	
STOCK CARRYING CAPACITY (s.iu/ha)	10, 11, 15	12, 16, 20	
SITE INDEX (m)	28-31	23-35	10, 11, 12-15* 27-33

tephra rather than flow tephra; these areas have neither Tp recorded in the rock type inventory nor a flow tephra derived soil. North of Mokai, Taupo Pumice on the upper hill slopes is shallower, so composite yellow-brown pumice soils on yellow-brown loams (Ngakuru series) are mapped in conjunction with Taupo hill soils formed on accumulated Taupo Pumice in the lower slopes. Because of its greater relief, Vie 19 also has much more erosion recorded than does IVel3 but it is mainly of slight severity.

Extensive sheep and cattle grazing occupies about 65% of the area and exotic forestry a further 20%. Because the potential stock carrying capacity is only medium*, undeveloped land in this LUC unit, as well as some of the low-producing pasture, would be well suited to exotic forestry. Exotic forestry potential is

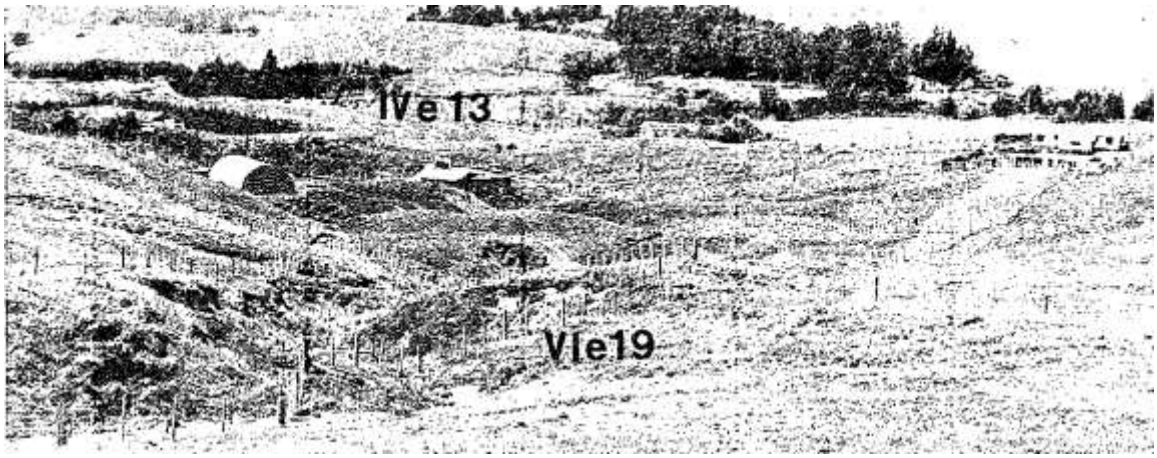


Fig. 90: LUC subsuite 7g: General view over Vie 19 (hills in foreground) and IVel3 (basin in middle of photo), on complexes of Taupo tephras. Taupo township and Mt Tauhara in background. Mapara Rd, Acacia Bay district, N94/475351 looking ENE.

***Parts of Vie 19 (less steep slopes and areas on finer water-sorted tephra derived soils) have a similar stock carrying capacity to IVel3 and it is considered that the potential stock carrying capacity of 12 su/ha stated in the extended legend is too low. However, a revision would probably not raise the potential above medium.**

variable and compliance with the "Forest Operations" guidelines (NWASCO 1976) would be desirable.

91: LUC subsuite 7g: IVel4 (foreground) and Vie 19 (behind) on complexes of Taupo tephras. Mt Tauhara Station, N94/584377 looking E.

92: LUC subsuite 7g: Vie 19 on eroded Oruanui breccia. Whangamata Rd, North Taupo district, N93/298466 looking E.

LUC SUITE 7h: TAUPO PUMICE ON THE KAINGAROA PLATEAU

General

This subsuite is characterised by moderately deep Taupo Pumice occurring in a distinctively cold and harsh climatic regime. It occurs on the Kaingaroa Plateau, a large uplifted plain which is physiographically equivalent to the Mamaku Plateau but differs in having considerably less rainfall and a much deeper mantle of Taupo Pumice, giving rise to yellow-brown pumice soils. The combination of infertile soils, harsh climate and a history of volcanic and cultural destruction of vegetation resulted in the barren appearance recorded by early European travellers. The area has, however, undergone a startling transformation to exotic forest. Planting started early this century and by the end of the 1930s the plateau was largely afforested, creating a plantation which has laid the basis for the growth of New Zealand's forestry industry in the last two decades.

The subsuite occupies 113,600 ha, 14% of the Taupo Pumice LUC suite and 6.5% of the total area of the region. There are five LUC units: IIIs7, Illell, IVelO, VIel2 and IVs5. The first four are differentiated according to slope and form a continuum, while the fifth is distinguished by soils and altitude. A feature of the subsuite is the large size and uniformity of the map units (average size nearly 500 ha), reflecting even topography.

The subsuite occurs principally on the Kaingaroa Plateau but also on the Upper Rangitaiki Plains to the south-east. However, it does not occupy all of the latter area, because much of this has been mapped in LUC subsuite 7f. This southern part, consisting dominantly of IVel8 (LUC subsuite 7f) and IVs5 (this subsuite), differs somewhat in parent materials from the northern part (remaining LUC units in this subsuite). However, both parts, as well as much of IVel8 (see p. 159 and Table 27b), have similarities in physiographic position, climate and soil properties that warrant their grouping together into this subsuite.

The northern part of the subsuite has been influenced by Kaharoa and Tarawera ashes as well as Taupo Pumice, and the north-eastern corner has been mapped as a complex of LUC subsuites 7h and 4a. The subsuite has also been mapped in a complex with LUC subsuite 7i where Waimihia lapilli underlies Taupo Pumice. It is bordered to the north and north-east by LUC subsuites 4a, 4b, 6a and 6b, and elsewhere by subsuites of the Taupo Pumice LUC suite.

Climate

The climate, compared with the rest of the Taupo LUC suite, is characterised by cold winters and cool temperatures throughout the rest of the year. There is a significant trend to colder temperatures in the south. Severe summer moisture deficits occur despite the cool temperatures. The representative climate station is Wairapukao.

Physiography

The physiography of the Kaingaroa Plateau has been described by Vucetich ***et al.*** (1960). The plateau is formed by a series of fault-bounded, overlapping ignimbrite flows, incised by steep gullies at the edges and stepped on the eastern flanks. It slo pes from just under 500 m a.s.l. in the north to about 700 m a.s.l, in the south.

In the south-east, the upper Rangitaiki River valley and nearby depressions have been deeply filled by Taupo deposits to form the Upper Rangitaiki Plains at an elevation of 700-750 m a.s.l. The surface of the plateau and the plains is almost all flat to gently rolling, but sometimes finely dissected. Strongly rolling to moderately steep slopes occur over only 15% of the subsuite, mainly on the periphery of the plateau.

Rock Type and Soil Parent Material

The lithology of Taupo Pumice in the subsuite area is very complex and has been described in detail by Pullar (1980). In particular, Taupo Sub-group members 1-3 are all prominent and there are close associations of airfall ("tephra-fall" of Pullar's terminology), flow ("tephra-flow") or water-sorted ("alluvium") tephras. In the north, airfall tephra is dominant because it is only shallowly overlain by flow tephra. However, in the south the flow tephra is thicker.

In this southern area LUC subsuite 7f has also been widely mapped. The total thickness of Taupo Pumice is approximately 1-3 m, being generally thinner in the north and thicker in the south-west. In the north, Taupo Pumice is overlain by Kaharoa Ash up to 1 m thick, but these areas have been included within this subsuite rather than in LUC suite 4 because of the climatic and physiographic unity of the plateau and also because Taupo Pumice is still present at tree rooting depth.

Ashes of the Rotorua Sub-group, which reach a considerable depth in the northern part of the plateau, are of special significance in this predominantly forested subsuite because tree roots can reach below the coarse infertile Taupo-derived soil horizons into the better moisture-holding and weathered paleosols formed on the 'Mo' ashes.

The underlying rock type is ignimbrite throughout except for very small areas of Huka sediments on the north-west margin. The ignimbrite is rarely seen because it is mantled with 3 to more than 15 m of tephras from the Taupo and Rotorua Sub-groups. In the south, considerable thickness of lapilli from the Waimihia Formation underlie the Taupo Pumice Formation. These are of special significance because of their erosion potential and have in places been mapped in a separate subsuite (7i).

Soils

About 60% of the area was mapped using soils from the Taupo Survey, about 30% using soils from the Kaingaroa Survey, and small areas from the Waiotapu, Whakatane and General Surveys.

All soils are yellow-brown pumice soils. Approximately 65% of the subsuite has soils derived from flow tephra or water-sorted tephra and 35%, mainly in the north, from airfall tephra*.

Although topsoils are loose and drought-prone, subsoil compaction has been a problem in forest establishment. The compaction was investigated by Pullar (1980) who considered that it was related partly to the presence of either pumice blocks or "grey lithics" within the Upper Taupo Pumice, but the distribution of these two facies was too irregular to allow it to be established definitely as the cause of subsoil compaction.

Erosion

Little erosion was recorded in this subsuite, a reflection of the gentle topography and the protection of the ground surface by forest vegetation cover. Slight erosion was recorded on map units covering 11% of the subsuite, occurring mainly in small pastoral areas on the fringe of the forest. The main erosion type was gully, with minor sheet, streambank and rill erosion. Most erosion in this subsuite was recorded in small map units rather than large homogeneous ones, with the result that the proportion of map units with erosion recorded was much greater than the proportion of total eroded area.

Potential erosion was assessed as being slight to severe and the dominant erosion association classified as R, with minor areas of association P.

Land Use and Land Management

Present land use is dominated by exotic forestry, which occupies more than 75% of the area. Present pastoral use, on the north-western fringes and in a firebreak strip running through the central Kaingaroa Forest, occupies only about 10% of the subsuite. The remaining areas, occurring on the Upper Rangitaiki Plains, have a mixture of pasture species, short tussock associations and ***Dracophyllum-dovamaltd*** heathland remnants. Most of this land is at present under development for pastoral use, although NWASCO (1982) recommends exotic forestry for undeveloped land in this subsuite. Over most of the southern Kaingaroa Plateau and Rangitaiki Plains any land development involving cultivation or soil compaction involves a severe erosion hazard. Therefore, any such development should carefully avoid

***If the portion of IVel8 that occurs on the Kaingaroa Plateau were to be included within this subsuite (see p. 159), about 75% of the soils would be derived from flow or water-sorted tephra. However, about 20% of the soils (Kaingaroa loamy sand) are derived from shallow flow tephra overlying airfall members of the Taupo Pumice Formation, as described above, and are similar to the soils derived from airfall tephra. (In the Kaingaroa Survey, these soils were mapped as Kaingaroa silty sand and were regarded as being derived from airfall tephra).**

gullies and waterways and use contour cultivation. Land development is generally limited by low soil fertility, harsh climate and the potential for gully erosion. It is interesting to note that forestry was developed on the Kaingaroa Plateau mainly for historical, economic and social reasons rather than on physical land resource criteria, and that the southern Kaingaroa Plateau is, in terms of site index, one of the least productive large forest plantations in the North Island.

LUC Units on Taupo Pumice on the Kaingaroa Plateau (Table 29)

LUC unit IIIs7 **(2,650 ha)—**Figures 93, 96

This LUC unit occurs on fiat to gently undulating land in the lower-lying northern part of the Kaingaroa Plateau, at approximately 500-550 m a.s.l. The largest areas occur around the northern boundary of Kaingaroa Forest and north of Wairapukao. IIIs7 has a deep cover of 'Mo' ashes and about 1 m of Taupo Pumice, usually overlain by 8-30 cm of Kaharoa Ash.

IIIs7 has a larger proportion of grazing land (more than 30%) than other LUC units in the subsuite, reflecting its position partly outside Kaingaroa Forest. These northern areas have a high potential for pastoral use and also a potential for diversified arable use. The northern margin of the Kaingaroa Plateau is somewhat sheltered and certainly less cold than most of the plateau, and although the Te Rere soils are drought-prone they have a compact subsoil horizon which enables them to retain more moisture than other soils derived from Kaharoa Ash*. The present land use pattern is not expected to change. Soil conservation measures are confined to establishment of windbreaks and maintenance of a complete grass cover in pastoral areas.

LUC unit Illell (12,300 ha)—Figure 94

This LUC unit is slightly more undulating and dissected than IIIs7, giving it a moderate erosion potential when cultivated. It occurs on the western side of the Kaingaroa Plateau, usually immediately adjacent to its edge, up to 640 m a.s.l. It is often dissected by steep gullies leading back from the edge of the plateau (VIIe4 (LUC subsuite 8c) in the north and VIIe6 (LUC subsuite 7e) in the south).

Illell has a slightly greater proportion of its area covered by exotic forest than has IIIs7 but it is very similar in land use potential and management requirements, as well as in its recorded inventory factors. One significant difference is that Illell has a smaller proportion of Te Rere soils and therefore less potential for diversification of the non-afforested areas, but it has a high potential stock carrying capacity.

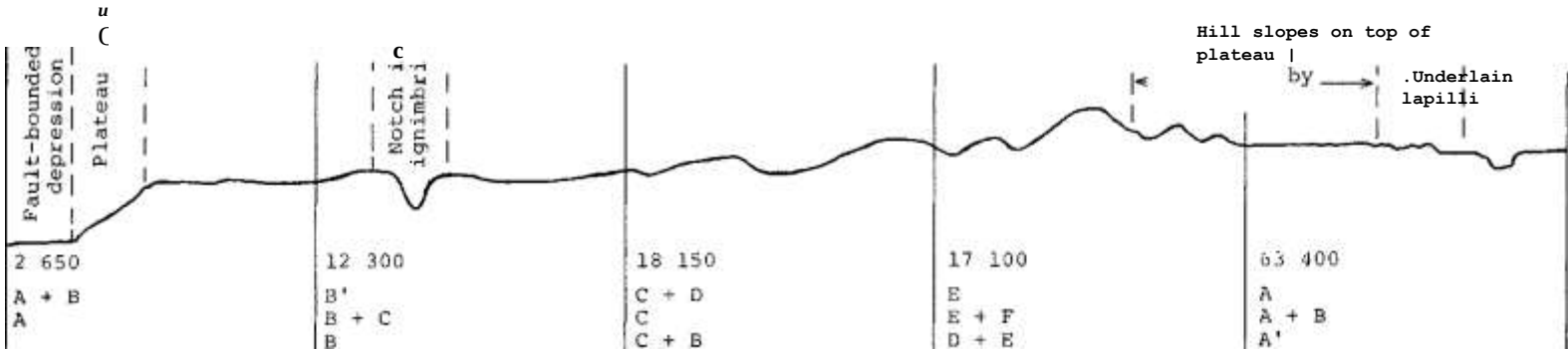
LUC unit IVe10 (18,150 ha)—Figure 94

This LUC unit occurs on rolling to strongly rolling slopes on the northern and central Kaingaroa Plateau which have a thin mantle of Kaharoa Ash over Taupo Pumice. It is especially widespread in the north-east of the subsuite where it and Vie 12 are mapped together with Vllel (LUC subsuite 4a) on the dissected and stepped corner of the plateau bordering the Galatea Basin. Because of its location IVelO is heavily influenced by Kaharoa Ash, but this is underlain by at least 50 cm of Taupo Pumice. Most of the Taupo Pumice occurring on IVelO (and Vie 12) is airfall tephra without a significant flow tephra component, hence Kaingaroa series soils are not widespread. Rolling slopes on flow tephra are mapped in IVel8 (LUC subsuite 7f).

IVe10 is generally similar to Illell apart from its greater slopes and greater influence of Kaharoa Ash. Northern areas occur at a slightly lower altitude and are probably slightly warmer but a potential for severe erosion under cultivation precludes arable use other than occasional supplementary fodder cropping. Pastoral use is very minor and the potential stock carrying capacity shown in the extended legend is probably slightly optimistic. Exotic forest is a more suitable land use for this LUC unit but management should comply with the "Forest Operations" guidelines (NWASCO 1976), especially in areas dissected by steep gullies.

TABLE 29: LUC units on Taupo Pumice on the Kaingaroa Plateau.

LUC UNIT	IIIs7	IIIe1 1	IVe10	VIe12	IVs5
RELATED LUC UNIT (LUC Suite)	IIIs4 (4b) | Vllel (4a)| Vllel | (4a) I || j-Ignimbr tephra	IVel8, iVIe24 | (7f) ,1			
PHYSIOGRAPHY	ite plateau, mainly mantled with airfall- but with pockets of flow	Flow high altitude basin	tephra	mantled-	



	tephra				
% MAP UNITS CONTAINING EROSION		Kaingaroa (loamy sand) Te Rere	26-31 Kaingaroa (loamy sand) Te Rere	26-34 Pekepeke Taupo Kaingaroa (loamy sand]	Kaingaroa Otamatea Te Rere
PRESENT EROSION					14
POTENTIAL EROSION			6		1G
		0(lSh,W,Sb)	1G	12	1G,W(3G,W)
AREA (ha)					
PRESENT LAND USE			0(2Sh,W,G)		
SLOPES		Exotic forest Sheep & cattle		Exotic forest Sheep & cattle	Exotic forest Sheep & cattle Undeveloped
STOCK CARRYING CAPACITY (s.u./ha)			Exotic forest Sheep & cattle		
SOILS		14, 19, 22		13, 15, 20	11, 15, 15"
SITE INDEX (m)			14, 29, 25		

ISh

lSh,W(3W,Sh,R)

Exotic forest
Sheep & cattle
Undeveloped

14, 19, 25

29-36

Pekepeke
Matahina
Taupo

16

lSh,Sb

29-36

2Sh; lsSl,Sb

LUC unit IVs5 (63,400 ha)—Figures 95, 97

This LUC unit occurs on fiat to gently rolling surfaces between 550 and 750 m a.s.l. with soils formed dominantly from Taupo flow tephra. It is the most extensive LUC unit in the subsuite. Its higher altitude and the nature of the soil parent material distinguishes it from IIIs7. (For this reason the area of IVs5 straddling State Highway 5 west of Kaingaroa Village where Te Rere soils are mapped would be better classified as IIIs7.) It has more in common with the elevated central and southern parts of the Kaingaroa Plateau and Upper Rangitaiki Plains, especially with IVel8 (LUC subsuite 7f). On the Upper Rangitaiki Plains, IVs5 includes intermediate river terraces with soils formed from water-sorted Taupo tephra (Poronui soils).

In southern Kaingaroa and the Upper Rangitaiki Plains, Taupo Pumice is underlain by deep Waimihia lapilli. Where the land is flat the influence of these lapilli on land use capability is negligible and IVs5 was mapped. However, where the land is undulating to rolling their influence is more important and these areas have been classified as IVel7 (LUC subsuite 7i). IVs5 has only slight gully erosion, but there is a potential for severe gully erosion under cultivation.

Present land use is dominated by exotic forestry, with most of the rest presently being developed for pastoral use. Potential stock carrying capacity is only medium, and is severely limited by infertile soils, erosion risk, and cold temperatures. However, exotic forestry potential is also low to medium, largely due to tree establishment problems related to subsoil compaction (Pullar 1980). (These problems can be decreased by ripping before establishment.) Therefore, the present land use pattern may well be maintained provided that present land development for pastoral use is successful. Soil conservation measures include maintenance of grass cover, provision of shelter, prevention of gully initiation, and compliance with the "Forest Operations" guidelines (NWASCO 1976).

LUC unit VIel2 (17,100 ha)—Figure 96

This LUC unit occurs on strongly rolling to moderately steep hill slopes. It has a similar distribution to IVelO, occurring mainly in the north-eastern corner of the Kaingaroa Plateau up to 500 m a.s.l. It is also scattered through the northern and central areas up to 650 m a.s.l., where it sometimes occurs on the edge of the Kaingaroa Ignimbrite flow and as small hills mantled with Taupo airfall tephra that rise above plateau areas dominated by flow tephra. It also 'outcrops' to the north-west of the Kaingaroa Plateau where small resistant ignimbrite cones occur south of Lake Rerewhakaaitu. In its southern area, it is underlain by lapilli from the Waimihia Formation, and as these become thicker Vie 12 grades into VIe22 and VIIel4 (both LUC subsuite 7i).

Over most of its area Vie 12 is similar to IVelO, both LUC units having soils derived predominantly from airfall tephra (including Kaharoa Ash) rather than flow tephra. In the hills at the north of the plateau there is a thin mantle of Tarawera ash and in this area VIel2 grades into VIe20 (LUC subsuite 6a). Compared with IVelO, there is a greater incidence of erosion, especially sheet erosion. Vie 12 has a slightly lower pastoral potential but similar exotic forestry site index to IVelO. Forest management should comply with the "Forest Operations" guidelines (NWASCO 1976), and pastoral management should aim for maintenance of grass cover to reduce sheet erosion. Extensive grazing occupies about 17% of the area but the LUC unit is generally more suitable for exotic forestry.

Jig. 93: **LUC subsuite 7h: IIIs7. Wairapukao, N95/027563 looking SW.**

Tig. 94: **LUC subsuite 7h: Illel** 1 **(foreground) and IVelO (behind) under pastoral use on v edge of Kaingaroa Plateau. Rawhiti Rd, Broadlands district, N85/873640 looking E.**

Fig. 95: **LUC subsuite 7h: IVs5 on southern Kaingaroa Plateau on flow tephra underlain by Waimahia lapilli. Hills in left background are predominantly VIe22 (LUC subsuite 7i), with northern Kaimanawa Range behind. Wairongo Rd, Iwitahi district, N103/723188 looking S.**

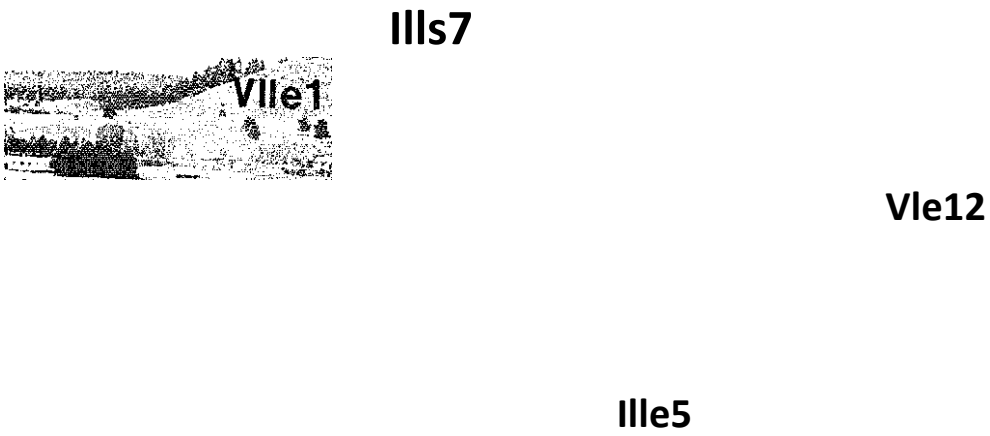


Fig. 96: **LUC subsuite 7h: General view of northern edge of Kaingaroa Plateau, with Vie 12 on scarp and IIIs7 on flat areas on skyline. Vllel (LUC subsuite 4a) on steeper parts of scarp to left and IIIe5 (LUC subsuite 4b) in foreground. Rerewhakaaitu district, N86/978819 looking S.**

LUC SUITE 7i: TAUPO PUMICE OVER WAIMIHIA LAPILLI

General

This subsuite is characterised by deep beds of lapilli, chiefly from the Waimihia Formation (Healy ***et al.*** 1964a), occurring beneath the Taupo Pumice deposits. These lapilli are very coarse textured and poorly compacted and consequently highly erodible when exposed to running water. This severe gully erosion potential constitutes a considerable constraint to land use capability.

The subsuite occurs on the central and southern Kaingaroa Plateau, the Upper Rangitaiki Plains, the upper catchment of the Whaeo River, the hills at the head of the Upper Rangitaiki Catchment, and in the eastern Taupo district north of the Hinemaiaia River (Fig. 55). It has an area of 36,750 ha, 5% of the area of the Taupo Pumice LUC suite and 2.1% of the total area of the region. There are three LUC units: IVel7, VIe22 and VIIel4. Flat land within the subsuite area, where underlying lapilli beds do not significantly affect land use capability, is included in IVs5 (LUC subsuite 7h) (see p. 176). The four LUC units form a continuum from flat land to steep hills.

The subsuite is closely related to LUC subsuites 7f and 7h in the southern Kaingaroa Plateau and all other areas underlain by Waimihia lapilli. It is bounded by subsuites on Taupo airfall and flow tephra (7c, 7f and 7g), and in steeper areas on the south-eastern boundary of the region by LUC subsuite 7e. Waimihia lapilli also occurs across this boundary in the Northern Hawke's Bay Region and all three LUC units of this subsuite correlate with LUC units in that region.

Climate

The representative climate station for this subsuite is Waimihia Forest. The climate here is slightly wetter and cooler than that experienced further north on the Kaingaroa Plateau. There is considerable variation in annual rainfall, from more than 2000 mm on higher-lying areas to about 1300 mm close to Lake Taupo.

Physiography

Most of the subsuite lies at an altitude of 550-750 m a.s.l., with hills on the catchment boundaries rising to just over 900 m a.s.l. Relief is varied but is predominantly rolling to moderately steep hills. The subsuite occurs in three physiographic situations:

a) On the Kaingaroa Plateau, mainly on the edges of the youngest ignimbrite flow which forms a slight ridge running down the plateau.
b) On rolling country and hills rising above the flow tephra on the Upper Rangitaiki Basin and surrounding the basin, which divide catchments draining to the north (Whirinaki, Whaeo and Rangitaiki) from those draining to the south (Mohaka and Waipunga). These hills have a rounded appearance similar to that of hill country in the Matahina district which is underlain by deep Mangaone Lapilli (see p. 95).
c) On hill country to the east of Lake Taupo, where a dissected breccia block is partially infilled by flow tephra.

Rock Type and Soil Parent Material

Lapilli was recorded throughout the subsuite. Waimihia lapilli, a member of the Taupo Sub-group dating from about 3400 yr BP, constitutes the main member of the Waimihia Formation. It is a vesicular, angular, rhyolitic pumice which is present to a depth of at least 1 m throughout the subsuite and up to 6 m in places (Pullar 1980; Walker 1981). In some areas, Hatepe Lapilli (Healy ***et al.*** 1964a; Walker 1981) is also present to a significant depth within the Taupo Pumice Formation. Taupo Pumice Formation itself was recorded over Waimihia lapilli throughout the subsuite, except on the steepest slopes. It included Taupo flow tephra over much of the area, as in LUC subsuite 7h, but where flow tephra dominated LUC subsuite 7f was mapped.

Underlying rocks include Rangitaiki and Te Whaiti Ignimbrites, Kaweka Greywacke and smaller areas of Oruanui breccia, with intervening depressions infilled with Taupo flow

tephra. However, the underlying rock type has only been recorded on about 35% of the subsuite (in steeper areas). Over the rest, deep Taupo Sub-group and older 'Mo' tephras including Tongariro Ash and Oruanui Ash were the only rock types recorded.

Soils

The whole subsuite was mapped using soils from the Taupo Survey, all classified as yellow-brown pumice soils or related steepland soils. Most are derived from airfall tephra; those derived from flow or water-sorted tephra (Kaingaroa, Otamatea series) are recorded on only 5% of the subsuite area (excluding IVs5).

A feature of this subsuite is the relatively high rainfall, the soils on about 75% of the subsuite being either podzolised (Tihoi and Pukerimu series) or moderately leached soils (Oruanui series). In the eastern Taupo district significant areas of both Oruanui and Taupo soils were recorded, a reflection of the variation in rainfall, although Taupo soils may have been over-recorded.

Erosion

Slight erosion was recorded on map units covering 21% of the subsuite, moderate erosion on map units covering 2%, and severe erosion on map units covering 1%. Gully and sheet were the main erosion types recorded, being of approximately equal significance at all severities. Potential erosion is assessed as moderate to severe and the erosion associations classified as R and P. There is an especially severe potential for gully erosion if the lapilli are exposed. The low incidence of present erosion probably reflects the limited amount of soil disturbance through cultivation or land clearance; on land with a predominantly pasture cover, map units covering nearly 80% of the area had sheet or gully erosion recorded.

Land Use and Land Management

Exotic forestry is the major land use, occupying nearly 60% of the area at the time of mapping, on both state (mainly Waimihia State Forest) and private land. This proportion will have increased considerably since then. Undeveloped land occupies about 25% of the area. This comprises indigenous scrub or forest communities, especially manuka, beech forest or podocarp-hardwood forest in which some logging has taken place. Pastoral use occurs on the remaining area, being mainly extensive grazing with small areas of land being developed through cultivation of fodder crops.

Land in this subsuite has only medium potential stock carrying capacities, with production being limited by a harsh climate, poor soils and a continuing erosion potential. Most pastoral use will occur on limited areas of rolling land farmed in conjunction with flat areas (LUC subsuites 7f and 7h) on the Upper Rangitaiki Plains. Exotic forestry has been recommended by NWASCO (1982) throughout the subsuite, although site indices are variable. Some of the steeper land is more suitable for catchment protection or erosion control forestry, while small areas of forest in the southern part of the subsuite have been zoned for protection within Kaimanawa State Forest Park. Soil conservation practices required are similar to those for the rest of the Upper Rangitaiki district, but particular attention must be paid to gully control and minimum disturbance during construction of tracks, so as to avoid exposure of the lapilli. Compliance with the "Forest Operations" guidelines (NWASCO 1976) is essential on all LUC units.

LUC Units on Waimihia Lapilli (Table 30)

LUC unit IVel7 (11**,250 ha)—**Figures 97, 98

This LUC unit occurs on undulating to rolling land throughout the subsuite although it is not common in the eastern Taupo district. It forms a slope continuum with IVs5 (LUC subsuite 7h). It generally occurs in the middle range of rainfall experienced through the subsuite. Exotic forestry covers 66% of the LUC unit, while the remaining 34% is fairly equally divided between extensive grazing, indigenous logging, and undeveloped land. Some further pastoral use could be undertaken in conjunction with farm development that concentrates on IVs5 but cultivation should only be undertaken as part of a pasture renewal programme. Exotic forestry appears to be generally a more suitable land use on this LUC unit.

TABLE 30: LUC units on Taupo Pumice over Waimihia lapilli.

LUC UNIT	IVe17	VIe22	Vile 14
RELATED LUC UNIT (LUC Suite)	IVel (7f) 8 IVs5 (7h)		VIIe6 (7e) VIIIe3 (8a)
PHYSIOGRAPHY	—Elevated olain ---------	Rolling hill country	Moderately steep I hills
AREA (ha)	11 250	16 400	9 100
SLOPES	■e -- ! --- ■ ----S—Underlain by Waimihia Lapilli-		
SOILS			r Mountain-land with patchy tephra cover
% MAP UNITS CONTAINING EROSION			E
PRESENT EROSION			F
POTENTIAL EROSION	lSh,G (3G,Sh,R; 2W)	lSh,G 2-3G,Sh	lSh,G,sSl 3Sh,G; lsSl
PRESENT LAND USE	Exotic forest Extensive grazing Indigenous milling Undeveloped	Exotic forestry Extensive grazing Undeveloped Indigenous milling	Exotic forest Undeveloped Extensive grazing Indigenous milling
STOCK CARRYING CAPACITY (s.uVha)	9, 9, 11		
SITE INDEX (m)	23-30 + E	10, 10, 12	8, 8, 11
Oruanui Pukerimu	Pukerimu Taupo Tihoi Oruanui	24-39 Tihoi Oruanui Tauhara	20-27
20	22		
1G		29	

LUC unit VIe22 (16,400 ha)—Figures 95, 97, 98, 99

This LUC unit occurs on rolling to strongly rolling slopes throughout the subsuite. It is most extensive in the Waimihia State Forest south of Iwitahi. It is generally similar to IVel7 except for slightly steeper slopes which give rise to a moderate to severe erosion potential. However, present erosion on VIe22 is not more severe than on IVel7 because of its predominantly woody vegetation cover. Exotic forest covers about 60% of the LUC unit and undeveloped land, on which some indigenous milling is taking place, about 25%. The remainder is used for extensive grazing. Pastoral land use will not increase very greatly under the farm development that is occurring on the Upper Rangitaiki Plains because this development is concentrated on the flat land (IVs5). VIe22 is more suitable for exotic forestry than for pastoral use, although the exotic forestry site index given in the regional extended legend is extremely variable. It is considered that most areas of this LUC unit have a similar exotic forestry potential to that of IVel7.

LUC unit VIIel4 (9,100 ha)—Figures 97, 98, 99

This LUC unit occurs on moderately steep to steep hills around the Upper Rangitaiki Basin and in the eastern Taupo district. It forms a continuum with VIe22 with which it is fairly similar, although more severe erosion occurs on the steeper slopes and there is a potential for severe gully and sheet erosion. It has steepland soils recorded on about 20% of its area, but the cover of Taupo Pumice is fairly complete on these soils except on the steepest slopes. Exotic forestry and undeveloped land each occupy about 45% of the area. Grazing is a minor land use and some indigenous milling takes place on forested land. Vile 14 is more suitable for exotic forestry than for pastoral use, although its potential is variable and some areas would be better used for erosion control or catchment protection forestry.

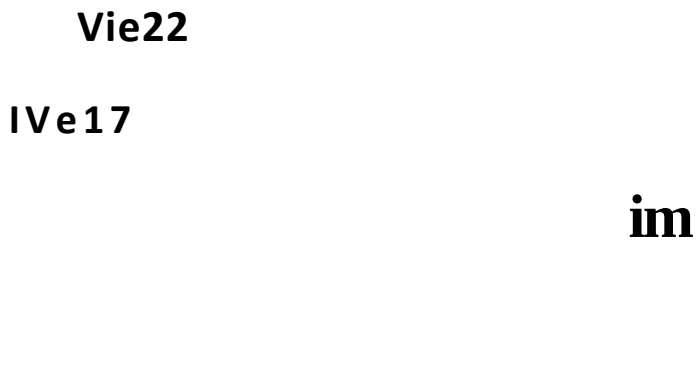
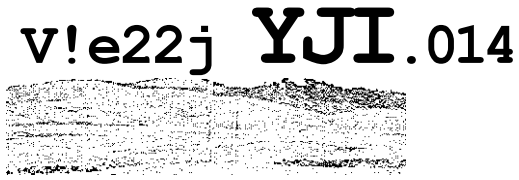


Fig. 97: **LUC subsuite 7i: General view over southern Kaingaroa Plateau, with IVs5 (LUC subsuite 7h) on flat land, IVel7 behind on undulating slopes, and VIe22 on hills in background, with Vile 14 on steeper slopes. Vile** 14 **also on slopes in foreground. Wairongo Lookout, N103/721129 looking** NE.



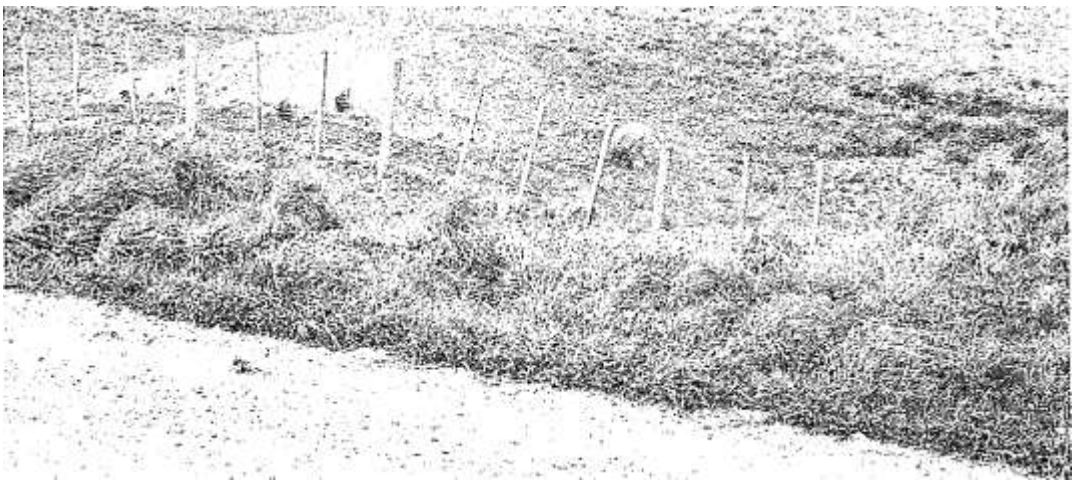


Fig. 98: **LUC subsuite 7i: Pastoral development on IVel7, with VIe22 behind and VIIel4 to right. Note coarse soil texture. Rangitaiki Land Development Block, N104/901158 looking** E.

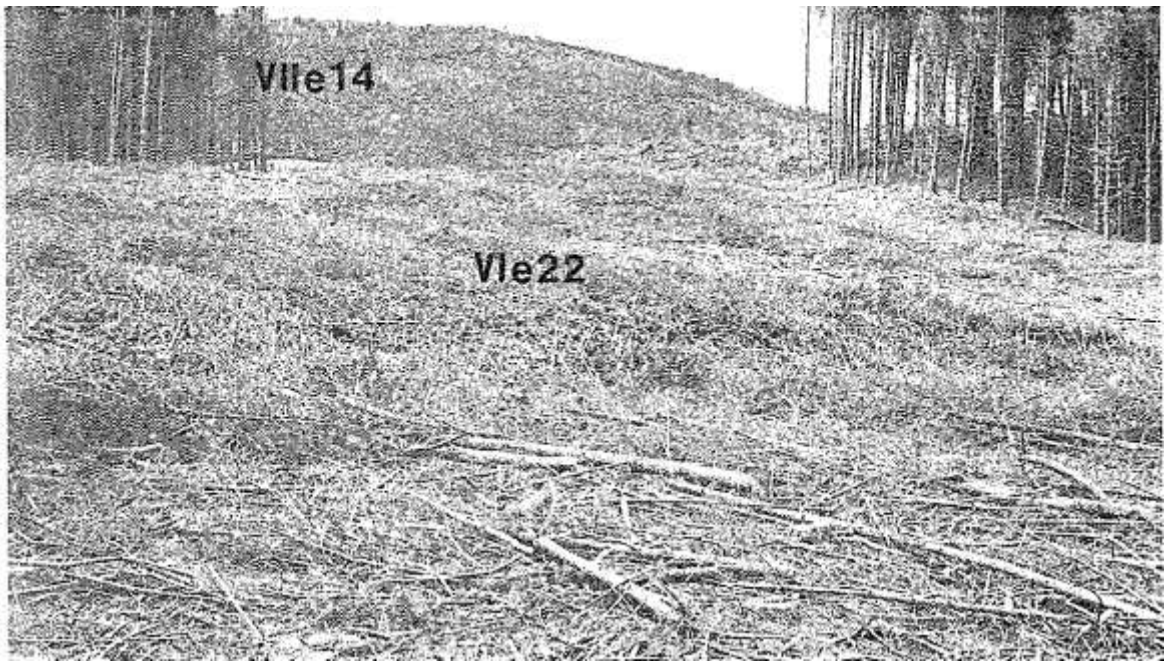


Fig. 99: LUC subsuite 7i: VIe22 (foreground) and VIIel4 on hill behind. Waimihia Forest, N103/758141 looking E.

LUC SUITE 8: STEEPLANDS AND MOUNTAINS

General

This LUC suite includes mountains, steep lowland ranges and other conspicuous steepland areas, such as large gullies, deep valley systems and rock faces, throughout the region. Its main characteristic is its general 'mountainland and steepland' environment. It is not all steepland because it includes rolling mountain tops, but by far the greatest part is steep to very steep. (See Nicholls (1976) for comparable use of the term 'upland and steepland' with reference to forest types.)

Because this LUC suite occurs throughout the region at varying distances from the main volcanic centres, it has very variable thicknesses of tephra. This is largely controlled by relief, so that very steep slopes and exposed tops above the treeline have little or no tephra cover, especially of the more recent ashes, and much bare rock, while lower slopes and ridges may have considerable thicknesses of tephra. In general, because of the steep mountain environment, underlying rock type is a much more significant factor in determining land use capability than is the tephra cover. Climate over this LUC suite is also very variable, ranging from a warm temperate coastal regime to the exposed high mountain environment of the central North Island mountains. However, rainfall is generally high. The land is mainly undeveloped and covered with indigenous woody vegetation. Indigenous logging has occurred in many areas in the past but present use of all kinds is of very low intensity; there is no arable land and very little land with significant pastoral potential. The most important land use is watershed protection.

The main areas of this LUC suite (Fig. 100) are the mountain lands of the Urewera, the Kaimanawa and Kaimai Ranges, and the Tongariro Volcanic Centre. It also occurs on the edges of the Mamaku Plateau, parts of the Rangitoto Range and Paeroa Range, and on many more isolated peaks, e.g., Mts Pihanga and Tarawera. The only main steeplands and mountainlands not included in this LUC suite are those with thick Taupo Pumice (LUC subsuite 7e), or recent tephras (LUC suite 6). Most of the LUC class VIII land in the region is in this LUC suite. Therefore it occurs throughout the region within most other LUC suites, usually in steepland gullies and valleys.

The area of LUC suite 8 is 358,350 ha, 20.1% of the total area of the region. This area is only exceeded by the Taupo Pumice LUC suite. It is divided into three subsuites. The first includes most of the steeplands and mountains. The other two, which are much less extensive, occur on distinctive rock types in more restricted situations.

LUC SUBSUITE 8a: GENERAL STEEPLANDS AND MOUNTAINS

General

This subsuite occurs on most of the mountain lands and steeplands described in the preceding section. It is the largest subsuite in the region and contains the two most extensive LUC units. Its distribution (Fig. 100) includes all the areas mentioned in the previous section, except for the Rangitoto Range, the edges of the Mamaku Plateau, and the steeplands of the Mangakino-Taupo area. It borders onto the other two subsuites of this LUC suite, as well as several other LUC suites which have related LUC units, e.g., LUC suite 5 and subsuite 8c in the Kaimai Ranges, LUC subsuite 7e in the Kaimanawa Range and the southern Urewera ranges, and LUC subsuite 6c in the Rangipo Desert. Small steepland areas that occur within most other LUC suites are mapped in this subsuite.

The area of the subsuite is 280,000 ha, 78% of the LUC suite, and 15.7% of the total area of the region. There are seven LUC units: VIe21, VllelO, VIIIe3, VIIIe4, VIIIe6, VIIIe7 and VIIIcl. They are differentiated by slope, altitude and severity of erosion. Three of the LUC units occur almost entirely on the high southern mountain areas above the treeline (Table 31b). Within the remaining LUC units (Table 31a) there are also differences

Fig. 100: Distribution of LUC suite 8. Small letters a, b and c show the LUC subsuites 8a, 8b and 8c respectively.

between those areas in the main ranges and those in steepland areas elsewhere. However, in terms of land use capability these, differences are relatively unimportant so that the LUC units in all three situations have been grouped into one large subsuite.

Climate

The main climatic characteristic of this subsuite is a high rainfall of relatively even seasonal distribution. Annual rainfall over almost all of the subsuite is greater than 1600 mm, and large areas receive more than 2000 mm. Temperatures vary more widely because there is a considerable altitudinal as well as latitudinal range. Many parts of the subsuite, especially to the south, are subject to frequent frosts throughout the year. Snow can fall at any time of the year on upland areas, and lies for much of the year in southern areas, while northern areas are more foggy. There are no representative climate stations within the subsuite, although Minginui, Waimana, and Chateau Tongariro lie just outside it.

Physiography

The main areas in the east of the region occur on the uplifted mountain blocks of the Urewera ranges and Kaimanawa Range which form part of the axial ranges of New Zealand. Within the Bay of Plenty-Volcanic Plateau Region these are bounded to the west by major faults such as the Kaimanawa, Whaeo and Waihou Faults, and rise to heights of 1694 m (Karikaringa) in the Kaimanawa Range and 1366 m (Maungapohatu) in the Urewera ranges. In the south the andesitic cones of the Tongariro Volcanic Centre rise to a height of 2751 m on Paretetaitonga Peak, Mt Ruapehu. The other main area is in the far north of the region on the Kaimai Range comprised of Upper Tertiary volcanic rocks, rising to 953 m at Mt Te Aroha. It is bounded to the west by the Hauraki Fault. Other areas of the subsuite include extruded volcanic cones (e.g., Mt Tarawera), fault blocks (e.g., Paeroa Range) and deeply dissected ignimbrite or breccia surfaces (e.g., gullies on the northern Mamaku and Kaharoa Plateaux).

The general relief pattern is one of long, steep to very steep slopes with moderately steep top slope and ridge portions. There are small areas of undulating to strongly rolling alpine tops in the south of the region.

Rock Type and Soil Parent Material

The tephra cover on this subsuite is very varied both in depth and composition. Total depth is generally 2-3 m throughout the Kaimanawa Range and the Urewera ranges, but is less than 1 m over much of the Kaimai Range and may be absent from large areas of exposed slopes and tops above the treeline (VIIIe6 and VIIIe7). 'Mo' ashes are recorded in the rock type inventory over 88% of the area, although over 20% they are only significant in patches. They consist of dominantly Pleistocene weathered ashes in the west and north, Rotorua Sub-group tephras in the centre and the Urewera ranges, and Tongariro Sub-group tephras in the south. Taupo Pumice and Waimihia lapilli occur to a depth of 20-60 cm on the tops of the Urewera ranges and the Kaimanawa Range where they are frequently recorded in the rock type inventory. Traces of Kaharoa or Taupo ashes occur in other steepland areas, and of Ngauruhoe ash in the south. However, most mountainous areas with thick recent tephras have been included in LUC suite 6 (see VIIIcl below).

Underlying rocks are more significant than tephras in this subsuite (see p. 184). The main basal rock type is greywacke, which is recorded over about 75% of the area. Greywackes in this region cover the full range of indurated sandstones, siltstones and mudstones described in Crippen & Eyles (1985), including some areas of Kaimanawa Schists as well as less indurated Cretaceous siltstones and sandstones in the central Urewera ranges. The other main basal recorded rock type is 'hard' volcanic rock (Vo), mainly andesites from the Tongariro Volcanic Centre cones, but also including minor areas of ignimbrites, dacites and andesites in the Kaimai Range. Minor rock types, occurring mainly in lowland steepland areas, include breccias, sandstones, lahars and various sedimentary deposits.

Soils

67% of the area of the subsuite was mapped using soils from the Whakatane Survey, 17% from the Taupo Survey, 12% from the General Survey, and small areas from the Waiotapu, Rotorua, King Country and Piako Surveys. The most extensive soil group, covering about 75% of the subsuite, was steepland soils related to podzolised yellow-brown pumice soils, reflecting the generally high rainfall. The single most extensive soil unit, Urewera steepland soils, has traces of Kaharoa Ash on Taupo Pumice and Waimihia lapilli over 'Mo' ashes over greywacke. Some steepland soils show a greater influence of Kaharoa Ash (Otanewainuku series) or Ngauruhoe ash (Kaimanawa series). Other steepland soils are related to yellow-brown pumice soils, in lower rainfall environments, (e.g., Motumoa and Paretotara series). Remaining soils were hill soils occurring on less steep areas. These were mainly podzolised yellow-brown pumice soils (e.g., Ruakituri, Matawai, Mangatepopo series). Bare rock was widely recorded, as were unspecified mountain soils and ice in the central mountains.

Erosion

Slight erosion was recorded on map units covering 61% of the subsuite, moderate erosion on map units covering 19% and severe to extreme erosion on map units covering 2%. The main types of erosion were debris avalanche and soil slip, recorded on map units covering 55% and 42% of the area respectively. (Debris avalanche was over-represented in area compared to the number of affected map units (39%).) Debris avalanche and soil slip usually occurred at slight to moderate severity and were often recorded together. Other less widely occurring types of erosion were gully, scree, sheet and wind, these last three often being recorded together at severe to extreme severity.

There are thus two combinations of erosion in this subsuite: soil slip and debris avalanche (with minor associated gully) occurring on large forested ranges and steepland areas, and sheet, wind and scree occurring on the central volcanoes and tops of the southern ranges (see p. 27). The latter type of erosion is similar to that occurring on LUC subsuite 6c. These two erosion combinations occur in the lowland/montane and subalpine/alpine zones respectively and hence also coincide with differences between woody and herbaceous vegetation. A futher combination of debris avalanche, soil slip and earth slip may occur where there is a significant depth of lapilli, especially in the northern Urewera ranges. These areas border onto VIIe5 (LUC subsuite 4c) where this combination of erosion is characteristic.

Debris avalanche and soil slip erosion in the Kaimai Range has been studied by Jane & Green (1983b). They noted a concentration of erosion on steeper slopes above 600 m, and suggested a linkage of increased recent erosion with depleted vegetation and possibly episodic forest mortality (Jane & Green 1983a; implied also for the Huiarau Range by Grant 1963), but failed to demonstrate a link between erosion and aspect, slope, soil type or basement geology.

Land Use and Land Management

Exotic forest occupies 1% of the subsuite and extensive grazing about 2%; all the rest is undeveloped. Indigenous logging has been a significant land use in the past and continues in small areas. The vegetation is dominated by indigenous forest, which occupies just over 75% of the subsuite. About half of this is podocarp-hardwood forest, with smaller areas of beech, podocarp-hardwood-beech and hardwood forest (see p. 28 for references to forest descriptions). Indigenous milling, periodic forest mortality and other influences, such as those of introduced animals, have resulted in much forest disturbance. Scrub and forest-scrub mixtures, mainly of hardwood forest and mixed indigenous scrub, are recorded on about 15% of the subsuite. Non-woody vegetation, which occurs on the southern volcanic mountains, is dominated by red or bristle tussock, together with some subalpine herbs or small shrubs. These areas occupy 6% of the subsuite.

Although less than 50% of the subsuite is LUC Class VIII, little of the remainder is considered to be suitable for development because its production potential is low and exceeded by its value for water and soil protection. Exotic forest potentials are variable but mainly low due to shallow soils, poor growth rates and continuing erosion risk. Recommendations for exotic forestry on LUC units in this subsuite (NWASCO 1982) are based on small areas outside national parks which had been combined with other LUC units that are not generally comparable to this LUC suite.

Most of the subsuite occurs within Tongariro or Urewera National Parks and the Whirinaki, Kaimanawa or Kaimai-Mamaku State Forest Parks. Habitat conservation and recreation values are high. Areas not under the above tenure are mainly lowland steepland areas classified as LUC class VIII because their steepness precludes active management. Where development does take place on any land in this subsuite, necessary soil conservation measures include minimisation of bare ground exposure, open planting of potential slip faces where feasible, control of feral animals, and compliance with the "Forest Operations" guidelines (NWASCO 1976).

TABLE 31a: LUC units on general steeplands and mountainlands
a) lowland and montane.

LUC UNIT	VIIIe3	VIIe-10	VIe21	VIIIe3	VIIIe4
RELATED LUC UNIT (LUC Suite) PHYSIOGRAPHY	Lowland gullies	VIIIe6 (7e) VIIe5 (4c) taxn range Flanks of maj or ranges 1 Lowland mountain slopes	Lowland mountain range tops	Very steep lowland - montane mountain slopes	Eroded steep montane mountain slopes
AREA (ha)		126 150	22 800	109 450	4 500
SLOPES		F F + G F + E	E E + F D + E	G G + F	G G + F
SOILS		Urewera Te Teki	Ruakituri Matawai	Urewera Otanewainuku Kaimanawa	Urewera Tangatara
% MAP UNITS CONTAINING EROSION		77	34	77	100
PRESENT EROSION		l-2sSl,daF; ISh	lsSl,daF	l-2daF,sSl,Sh; lG,Sc	2-3daF,sSl,Sc; 2G
POTENTIAL EROSION		3sSl,daF; ISh	2sSl,daF,Sh	3-4daF,sSl; 2Sh,G	4daF; 3-4sSl,Sc,G
PRESENT LAND USE		Undeveloped Indigenous forestry Extensive grazing	Undeveloped Indigenous forestry Extensive grazing	Undeveloped Indigenous forestry	Undeveloped
STOCK CARRYING CAPACITY (s.u./ha)		4, 4, 7	-, -, 10	-, -, o	-, -, 0
SITE INDEX (m)		19-36	23-34	0	0

TABLE 31b: LUC units on general steeplands and mountainlands
b) high lands.

LUC UNIT		VIIIe6	VIIIe7	Viiid
RELATED LUC UNIT (LUC Suite)	VIIIe5 (6c) Vine 3 VIIIe4 (8a)			
PHYSIOGRAPHY	Mountain slopes below tree line	Predominantly steep mountain slopes about the tree line	Eroded mountain slopes above tree line	Mountain tops above tree line
AREA (ha)		7 400	8 000	1 700
SLOPES		G F E	G E + G E	C B"
SOILS		Mountain soils Urewera Kaimanawa	Mountain soils Kaimanawa Bare rock	Makahoe Mangatepopo Ngauruhoe
% MAP UNITS CON-TAINING EROSION		94	100	60
PRESENT EROSION		1-2daF,Sh,W,Sc,sSl	2-5W,Sh,Sc; 1G	2Sh; 1W
POTENTIAL EROSION		4W,Sh,Sc; 3daF,sSl	5W,Sh,Sc; 3G	2Sh,W
PRESENT LAND USE		Undeveloped	Undeveloped	Undeveloped
STOCK CARRYING CAPACITY (S.u/ha)		-, -, 0 0	-/ o 0	o 0
SITE INDEX (m)				

LUC Units on General Steeplands and Mountains (Tables 31a, b)

LUC unit VIe21 (22,800 ha)—Figure 101

This LUC unit consists of strongly rolling to moderately steep ridge tops in the central and northern Urewera ranges which have a mantle of Taupo and 'Mo' ashes over greywacke. It occurs mainly in the Whakatane and Waimana catchments, and around Maungapohatu. Because of its topographic position, VIe21 generally has a much thicker mantle of Taupo Pumice than other LUC units in this subsuite, and most of its soils are podzolised yellow-brown pumice soils. However, at the scale of mapping, it includes some steep slopes with steepland soils.

In the past, significant indigenous milling has occurred on VIe21, especially around Maungapohatu, but its vegetation overall is largely podocarp-hardwood forest, with some beech. It is now largely unused for agriculture or forestry, occurring entirely within Urewera National Park or on enclaves of private land within the Park. Because of its exposed situation, VIe21 has a lower potential than other LUC units with similar soils (e.g., VIe9, LUC subsuite 7c). For this reason and because access to much of the LUC unit is extremely difficult, it is unlikely that there will be significant further development for agriculture or production forestry.

LUC unit VllelO (126,150 ha)—Figures 22, 35, 101

This LUC unit occurs on steep to very steep mountain slopes with a potential for severe soil slip and debris avalanche erosion. It has the largest area of any LUC unit in the whole region, occurring throughout the Urewera ranges and the Kaimanawa Range. However, its recorded inventory factors do not vary as much as many other less extensive LUC units.

Greywacke is the underlying rock type virtually throughout, with steepland soils related to yellow-brown pumice soils. Urewera steepland soils are mapped over nearly 90% of its area. Past and present vegetation and land use patterns are similar to those on VIe21, but even less intensive. It is classified as LUC class VII because forestry is technically possible, but because production potentials are low and most of the area lies within National or State Forest Parks, little development is envisaged. On limited areas on the fringes of the ranges, where slopes are less steep and site indices higher, exotic forestry may be a suitable land use if the "Forestry Operations" guidelines (NWASCO 1976) are carefully adhered to.

LUC **unit VIIIe3 (109,450 ha)—**Figures 9, 22, 102, 103

This LUC unit occurs on long, very steep slopes in lowland and montane zones, with slight to moderate present erosion and a severe to very severe erosion potential. This is themost widely distributed LUC unit in the region, having been recorded on every worksheet.As well as occurring up to the treeline in mountain and range environments throughout,it is the main LUC unit mapped in very steep lowland gullies or steeplands, especially onthe northern Kaharoa and Mamaku Plateaux, and around the Rotorua Lakes. It occurs onvaried underlying rock types, including 'stable' volcanic rock types and 'unstable' breccias as well as greywacke. Because it occurs from the Kaimai to the Kaimanawa Ranges it has a variety of mantling tephras, variable climatic regimes and, therefore, a wide variety of soils.

Of all LUC units in the subsuite, VIIIe3 shows the greatest variation between areas in the eastern ranges and the lowland steeplands. Yet despite these differences the land use capability and general physical characteristics in the two areas are similar. Most of the LUC unit has slight to moderate present erosion but a potential for very severe erosion; therefore it is not recommended for any active land use. About 80% is forested but on the remainder the vegetation is varied; some areas have been milled in the past and many lowland areas have been subject to fires or to extensive grazing at the margins.

LUC **unit VIIIe4 (4,500 ha)—**Figures 9, 12, 102

This LUC unit occurs on long, very steep slopes in the lowland and montane zones, with moderate to severe present erosion. It was mapped mainly in the Kaimai Range and in the Horomanga catchment on the western edge of the Ikawhenua Range, as well as small areas scattered throughout the Urewera ranges, and on Mt Tarawera. It is generally very similar to VIIIe3 except for its more severe present erosion. It also occurs on a variety of rock types, although there is comparatively more on 'hard' volcanic rocks than on greywacke. It is not known whether the incidence or severity of erosion is related to the underlying rock type. Present vegetation cover is mainly indigenous forest but includes forest-scrub mixtures on eroded sites. There is no active land use. Minimising the erosion may be dependent on wild animal control.

LUC **unit VIIIe6 (7,400 ha)—**Figure 103

This LUC unit occurs on slopes above the treeline with slight to moderate present erosion. It was mapped on the central volcanic mountains, including the tops of Mts Pihanga and Kakaramea, and on the Kaimanawa Range between Mt Dowden and Waipahihi. It occurs above an altitude of 1100-1230 m on the central volcanoes (where the treeline is indistinct) or 1300-1400 m in the Kaimanawa Range. In mountain areas it is distinguished from VIIIe3 by its occurrence above the treeline where it is subject to predominantly sheet, wind and scree erosion, and has mainly non-woody vegetation. It therefore belongs in the 'high mountains' group of the subsuite.

VIIIe6 has variable slopes, ranging from strongly rolling to very steep. Slopes tend to be short because the treeline does not lie far below the summits of the ranges. There are many areas of bare rock and ice recorded, as well as unspecified mountain soils. Vegetation is dominated by subalpine herbs, small shrubs and bristle tussock.

LUC **unit VIIIe7 (8,000 ha)—**Figures 54, 105

This LUC unit occurs on slopes above the treeline with moderate to extreme present erosion. It was mapped on the tops of the central volcanoes, chiefly Ngauruhoe, and the Kaimanawa Range around Patutu and the Waipahihi catchment. It is distinguished from VIIIe6 by the severity of present erosion and a slightly greater erosion potential. (This distinction is the same as that made between VIIIe3 and VIIIe4). In all other respects VIIIe7 is very similar to VIIIe6.

LUC unit VIIIcl (1,700 ha)—Figures 54, 104

This LUC unit occurs on undulating to rolling mountain tops above the treeline. It differs from VIIIe6 and VIIIe7 by its much easier slopes and lesser erosion potential; hence its dominant limitation has been assessed as climate (arising from altitude) rather than erosion. VIIIcl has a rather scattered distribution. Areas on Mts Ngauruhoe and Ruapehu are mantled with thick Ngauruhoe ash and have been shown in the summary diagram for LUC subsuite 6c (Table 20), whilst areas with thinner Ngauruhoe ash occur on the tops of the Kaimanawa Range at about 1400-1500 m altitude, for example, near Ngapuketurua and Waipahihi Peaks. A small area has been recorded on the top of Mt Pureora at 1000-1170 m a.s.l., only partly above the treeline. Because of the relief, Taupo Pumice is often significant and soils are podzolised yellow-brown pumice soils or composite recent soils on yellow-brown pumice soils. Vegetation is low and mainly herbaceous. Slight surface erosion occurs, and there is a moderate erosion potential, despite the dominant climate limitation.

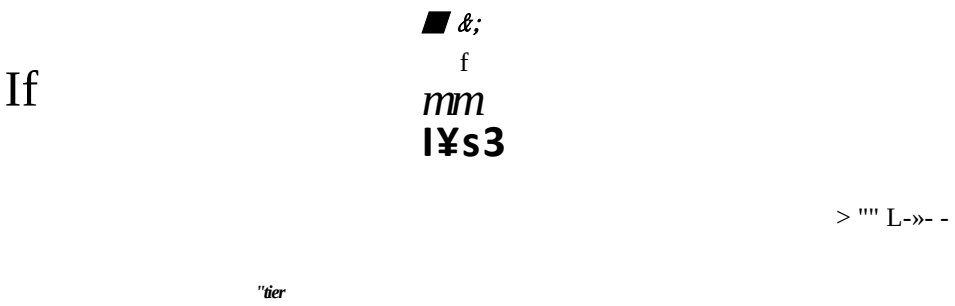


Fig. 101: **LUC subsuite 8a: VIe21 and VllelO in northern Ureweras. VIe21 in centre, VllelO to left and behind VIe21. IVs3 (LUC suite 3) on river flat in foreground. Waimana Valley, N87/547858 looking SSW.**

Fig. 102: **LUC subsuite 8a: General view of subsuite in western Kaimai Range. VIIIe3 and VIIIe4 on very steep faces at top of range, on uneroded and eroded slopes respectively. Steep lower slopes are VIIe4 (LUC subsuite 8c). Front hill country is VIel (LUC suite 1). Wairakau district, vie. N57/280690 looking SE.**

Fig. 103: **LUC subsuite 8a: General view showing relationship of subsuite to LUC suite 7 on Taupo Pumice, on Mt Pihanga. VIe9 (LUC subsuite 7c) on pastoral lower slopes, VIIe6 (LUC subsuite 7e) above, and VIIIe3 on highest forested slopes. VIIIe6 on top of mountain above treeline. IIIs6 on Taupo flow tephra (subsuite 7f) in foreground. Turangi district, Nl 12/290980 looking SW.**

104: **LUC subsuite 8a: General view of subsuite near Mt Ngauruhoe. In foreground is VIIIe5 (LUC subsuite 6c) on Ngauruhoe Tephra; on low ridge in midground is VIIIcl (this subsuite). Bare slopes on Mt Ngauruhoe and Tama Lakes area are VIIIe7. Piripiri Catchment, N122/217675 looking NW.**

105: **LUC subsuite 8a: Bare slopes on VIIIe7 above treeline. Waihohonu Track, Tongariro National Park, Nl 12/165752 looking NW.**

LUC SUBSUITE 8b: STEEPLANDS ON TERTIARY ROCK

General

This subsuite occurs on small areas of Tertiary sedimentary rocks which outcrop within two large mountain ranges in the region. These rocks are softer and more weathered than the greywackes and volcanic rocks which surround them, resulting in a more broken landscape and often allowing deeper soil profile development.

The main occurrence of the subsuite is in the central Urewera ranges, near Ruatahuna. It also occurs on the eastern Hauhungaroa Range in the vicinity of Hauhungaroa Trig (Fig. 100). The total area is only 4,900 ha, 1% of the area of LUC suite 8 and 0.3% of the total area of the region. By itself this subsuite is probably not large enough to be separately delineated, but large areas of similar land occur in the Northern Hawke's Bay and Gisborne-East Coast Regions and both LUC units correlate with LUC units in these two regions. There are two LUC units, VIel8 and Vllell (Figs. 106, 74). Because the subsuite is geographically very confined and homogeneous, the two LUC units are not separately described in the text but their characteristics are summarised in Table 32. Within the subsuite, LUC units on alluvium and Taupo flow tephra (LUC suite 3 and subsuite 7f) occur in the Ruatahuna Depression. In the Hauhungaroa Range, where there is a significant depth of Taupo Pumice, VIe9 and VIcl (LUC subsuites 7c and 7e on Taupo Pumice) are very similar to Vie 18 (this subsuite), especially where they occur on Tertiary rocks.

Climate

The climate in the Ruatahuna area is not as wet as in the rest of the Urewera ranges. It is mild in summer but cool in winter, with many frosts. Annual rainfall at Ruatahuna is 1632 mm. The area is sheltered from strong winds. The area on the Hauhungaroa Range has a climate similar to that described for LUC subsuites 7c and 7e. There are no representative climate stations in this subsuite, although the climate in the Ruatahuna area is similar to that at Minginui.

Physiography

The Ruatahuna Depression is a fault-bounded lens of rocks in the central Urewera ranges, exposed as an outlier of the major south-east dipping Tertiary sedimentary structure of the Waikaremoana-Wairoa district. The Whakatane and Ruatahuna Faults define a sharp boundary between the depression and the surrounding Urewera greywacke ranges. In the Hauhungaroa Range, the subsuite occurs on remnants of Miocene sedimentary rocks lying close to the Hauhungaroa Fault and surrounded by Pleistocene volcanic rocks. In both areas, the subsuite was recorded on rather broken hill country, with slopes of varying length, but generally steeper in the Hauhungaroa area. Vie 18 occurs on strongly rolling to moderately steep land while Vile 11 is recorded on dominantly steep slopes.

Rock Type and Soil Parent Material

A tephra cover with a total depth of 3-4 m mantles both areas of the subsuite. It consists of 'Mo' ashes from the Tongariro, Rotorua and Taupo Sub-groups, and Taupo Pumice. The latter is thick enough to be recorded in the rock type inventory in the Hauhungaroa Range (about 30% of the area of the subsuite) and is significant as a soil parent material throughout. In the Ruatahuna area Taupo Pumice is also overlain by thin Kaharoa Ash. The underlying rocks in both areas are Miocene sandstones, siltstones and mudstones, mapped as Sm, Mm, and occasionally Sb.

Soils

The Urewera portion of the subsuite is mapped using soils from the Whakatane Survey, and the Hauhungaroa portion using soils from the Taupo Survey. The soils recorded are mainly podzolised yellow-brown pumice soils or related steepland soils. Hill soils and steepland soils occur in roughly equal proportions. The most common soil overall is Ruakituri hill soil, formed from shallow Kaharoa Ash on Taupo Pumice and Waimihia lapilli over older

ashes. It is coarse-textured, infertile, and strongly leached. Steepland soils in the Ruatahuna district (Urewera series) are related to the Ruakituri soils, but in the Hauhungaroa Range they have a more variable tephra cover and are classified as steepland soils related to yellow-brown loams (Hauhungaroa and Whakapapa series).

Erosion

Slight erosion was recorded on map units covering 66% of the subsuite, moderate erosion on map units covering 9% and severe erosion on map units covering 10%. The main erosion types are soil slip and debris avalanche, with some sheet erosion (erosion associations G and C). Only slight soil slip and sheet was recorded on Vie 18, debris avalanche occurring on the more eroded and steeper land in Vllell. Potential erosion severity is assessed as moderate on Vie 18 and severe on Vllell.

Land Use and Land Management

The largest proportion of land in the subsuite is undeveloped, with indigenous milling having occurred widely in the past and still continuing to a small extent. The most common vegetation classes are logged podocarp-hardwood or hardwood forest and mixed indigenous scrub. The other main land use is extensive grazing, this mainly on VIel8 in the Ruatahuna

TABLE 32: LUC units on steeplands on tertiary rocks.

LUC UNIT	Vle18	Vllell
RELATED LUC UNIT (LUC Suite) PHYSIOGRAPHY	IIIs6 ' (7f) | IVs3 | (3) , Flow tephra „ , , .,, and river I BroJcen hills in fault bed in bounded depression valley_ | | | ^/	Steep hills on edge of fault bounded depression ./ ~\ iVIIelO ,(8a) Ivile6 |(7e) I , (Fault) /
AREA (ha)	2 500	2 400
SLOPES	E D + E	F
SOILS	Ruakituri Pokaka	Whakapapa Urewera Hauhungaroa
% MAP UNITS CONTAINING EROSION	87	83
PRESENT EROSION	lsSl,Sh	l-2daF; l-2sSl,Sh
POTENTIAL EROSION	2sSl,Sh	3daF,sSl; 2Sh
PRESENT LAND USE	Extensive grazing Undeveloped Indigenous logging	Undeveloped Indigenous logging Extensive grazing
STOCK CARRYING CAPACITY (s.u./ha)	5, 6, 11	4, 4, 7
SITE INDEX (m)	24-34	24-33

Sig. 13-

district. 40% of the subsuite has a vegetation cover of mixed grassland and scrub (mainly

mixed indigenous scrub or bracken), as well as some small forest remnants. Exotic forest is a minor land use, occupying 6% (Vllell only), all in the Waituhi Block (Pureora State Forest Park) in the Hauhungaroa Range.

Vie 18 has been given a slightly higher LUC ranking than VIe21 (LUC subsuite 8a) because of its more broken landscape with some less steep slopes and more weathered soils, and because it is situated within a valley rather than on the more exposed tops. On the other hand Vile 11 has been ranked marginally lower than Vile 10 (LUC subsuite 8a) because it was considered to be slightly more erodible. Overall the subsuite has a better potential for forestry than for pastoral use; exotic forestry is generally a suitable land use and its increase is recommended in NWASCO (1982). However, the Ruatahuna area is important economically as the largest and almost only significant area cleared and used pastorally in the Ureweras, hence this land use may be maintained, especially on Vie 18. The Hauhungaroa portion may be used more extensively for both exotic or indigenous forestry although higher slopes of the Hauhungaroa Range are unsuitable for production forestry. Part of the Waituhi State Forest is already zoned for long-term indigenous management. The "Forest Operations" guidelines (NWASCO 1976) should apply at all times. On pastoral land, soil conservation measures should aim at minimising the exposure of bare ground and should include open pole planting of potential slip faces where feasible.

Fig. 106: **LUC subsuite 8b: General view of subsuite on Tertiary sedimentary rocks. Vlel8 on moderately steep slopes in foreground, Vllell on steep slopes behind. Ruatahuna district, N96/395467 looking NE.**

LUC SUBSUITE 8c: STEEPLANDS ON HARD VOLCANIC ROCKS

General

This subsuite occurs on steepland areas on hard rock (usually volcanic), where soil-forming ashes are thin and there are significant outcrops of bare rock. Steepness, shallowness of the soils, occurrence of summer moisture deficits and the presence of bare rocks make this subsuite distinctive in terms of land use capability.

The subsuite is particularly widespread in the ignimbrite areas of the Kaimai Range, Mamaku Plateau, Rangitoto Range and western Taupo district. It is scattered elsewhere in the region, including some areas of rhyolite and basalt (Fig. 100). The climate over these diverse areas has been described under LUC suites 5 (Mamaku-Kaimai district), 7a (King Country-Rangitoto Range) and 7c (Whakamaru-Mangakino district). It has generally high rainfall and cool winters.

There are only two LUC units in this subsuite: VIIe4 and VIIIsl. They occupy an area of 73,450 ha, 21% of LUC suite 8 and 4.1% of the total area of the region. The grouping of these two LUC units into a subsuite is to some extent artificial, partly because VIIe4 is very varied. Because of the variation within and between these two LUC units no further general description of the subsuite is given, but both LUC units are more fully described individually. However, they have many common characteristics, most importantly their occurrence on bluffs with much bare rock. They occur together widely, especially along the Waikato River and in the Mangakino district. The subsuite has been widely mapped in association with LUC suite 5 on the edges of the Mamaku Plateau and the Kaimai Range, with LUC subsuite 7a in the Rangitoto Range, and with LUC subsuite 7c in the Mangakino-Whakamaru district.

LUC Units on Steepland on Hard Volcanic Rocks (Table 33)

LUC unit VIIe4 (66,250 ha)—Figures 12, 59, 107, 108

This LUC unit occurs on predominantly steep slopes with a patchy cover of Kaharoa, Taupo and 'Mo' ashes over hard rock types containing many bare rock faces. A map unit of VIIe4 typically includes sheer or nearly sheer rock faces as well as less steep colluvial footslopes. The LUC unit occurs in the Mamaku-Kaimai district, the King Country and the Rangitoto Ranges, and in the Waikato Valley in the Mangakino-Whakamaru district. It occurs mainly on ignimbrite in all these areas, as well as on more localised areas of greywacke, rhyolites, and various minor volcanic rocks. Vo is recorded as the underlying rock type over 80% of the area and greywacke over the rest. A tephra cover of older 'Mo' ashes was usually recorded although it is often only significant in patches. Bare rocks occur throughout. Thin Taupo Pumice is also usually present and was recorded as a rock type in some instances: VIIe4 is frequently mapped on steeplands within LUC subsuites 7a and 7b (shallow to moderately deep Taupo Pumice), being especially commonly associated with VIe5 (LUC subsuite 7a) with which it often forms a continuum. It may grade into VIIe6 (LUC subsuite 7e) on thick Taupo Pumice. There is thus a very wide range of soils on VIIe4, the three most common soil series covering only half of the area of the LUC unit. The most common soil, Otanewainuku steepland soil (General Survey), occurs in a wide range of situations with both Taupo and Kaharoa ashes and would be subdivided in future soil mapping. Apart from the soils shown in Table 33, other commonly recorded soil series from various surveys are Moturoa, Arahiwi, Ngaroma*, Mahorehore and Tauhara. Most of these are steepland soils related to podzolised yellow-brown pumice soils or composite soils. Where VIIe4 was mapped on Kaharoa Ash, on the eastern Kaimai Range and northern Mamaku Plateau, this LUC unit was chosen because of the 'rocky gorge' physiography, rather than its soils which are more closely related to those of Vllel (LUC subsuite 4a).

TABLE 33: LUC units on steeplands on hard volcanic rocks.

LUC UNIT	VIIe4			VIIIs 1	
RELATED LUC UNIT (LUC Suite)	IHe9, (5)	'IIIe4 ' (7a;	' VIe5 | (7a)	' VIe24 | (7f)	
PHYSIOGRAPHY	Plateau top Plateau scarp	Valley' Ui Ibottoml	Steep ignim-brite s lope	| Hill countr	Cliffl F-'-ow tephra in valley I bottom	Cliff
AREA (ha)	66 250			7 200	
SLOPES	F F + G F + E			G G + F	
SOILS % MAP UNITS CON-TAINING EROSION	Otanewainuku Moeatoa Aroha Bare rock 58			Bare rock Moturoa Otanewainuku Tauhara 27	
PRESENT EROSION	l-2Sh,sSl; ldaF,G			lSh,sSl	
POTENTIAL EROSION	3sSl,daF; 2Sh,G			lSh,sSl	
PRESENT LAND USE	Undeveloped Exotic forestry Extensive grazing Indigenous logging			Undeveloped Exotic forestry Extensive grazing	
STOCK CARRYING CAPACITY (s.u./ha)	13, 15, 15			- , - , 0	
SITE INDEX (m)	22-39			0	

Present erosion severity is only slight to moderate, because of the stable underlying rock type and the small area in pastoral use. However, there is a potential for severe erosion. About 50% of the LUC unit is forested, mainly with podocarp-hardwood and hardwood forest which has been extensively milled. 15% has indigenous scrub or forest-scrub mixtures. In total, undeveloped land (including small areas where indigenous milling still occurs) covers about 60% of the LUC unit. Exotic forest occurs on 26% and extensive grazing on about 13%. Pastures are poorly developed and usually have scrub or fern mixed with them. Pastoral use on VIIe4 occurs mainly in the Whakamaru district and east of the Rangitoto Range.

VIIe4 has a very variable exotic forest potential because of the wide range of soil depth and microtopography. NWASCO (1982) recommended a predominantly exotic forestry use. (In NWASCO (1982) it was considered that potential stock carrying capacity had been over- estimated in the NZLRI.) However, exotic forest suitability is also very variable and, in the past, severe erosion problems have been associated in some areas with clearfelling of indigenous forest, planting of exotic forest and associated road works (see, for example, p. 88). Most areas of VIIe4 are extremely important for catchment protection. Steeper slopes and gully heads are therefore not recommended for development. Much of the forested land also has a high wildlife conservation value (Saunders 1983; Imboden 1978), and include relatively rare indigenous forest types containing kauri in the north. Essential soil conservation measures on developed land include minimising of bare ground exposure, open pole planting of potential slip faces, and compliance with the "Forest Operations" guidelines (NWASCO 1976)

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LUC unit VIIIsl (7,200 ha)—Figure 108

This LUC unit occurs on very steep to vertical bluffs and cliffs of volcanic rock. It was recorded mainly in the gorges of the Waikato River between Ohakuri and Arapuni, and on the western and northern shores of Lake Taupo. It is scattered in other areas throughout the region, e.g., along the Tarawera River and the Paeroa Fault scarp. In some areas these bluffs and cliffs were mapped as VIIIe3 (LUC subsuite 8a) rather than VIIIsl, depending on a subjective decision on whether the dominant limitation was steepness and resulting erosion potential, or the rock surface itself. The sheer rock faces typically occurring within VIIe4 would, if large enough to be separately mapped (unusual because of the small horizontal displacement), be classified as VIIIsl.

The rock type was mapped as Vo throughout; it is generally ignimbrite but includes some rhyolite dome sides and the basaltic Karangahape cliffs on western Lake Taupo. Patchy tephra cover was recorded on a few areas which included less steep surfaces. However, erosion was not commonly recorded because of the bare rock surfaces. A variety of soils were recorded but bare rock was recorded throughout, and often as the first 'soil'.

VIIIsl usually has a scrubby vegetation cover, mainly of mixed indigenous scrub but including also ***Leptospermum,*** gorse or fern. Scrub or scrub-forest mixtures were recorded on nearly 80% of the area. The main type of forest vegetation is stunted hardwood associations but exotic pine trees also occur, mainly as self sown trees amongst scrub. Very small areas of exotic plantation or extensive grazing land occur on land surrounding the rock cliffs. These areas cover less than 10% of the LUC unit and apart from these inclusions, the steepness and rocky nature of the LUC unit preclude active uses. However, important hydro-electric development has occurred within this LUC unit, in the ignimbrite gorges of theWaikato River between Ohakuri and Arapuni.

Fig. 107: **LUC subsuite 8c: Combination of vertical ignimbrite bluffs and steep colluvial slopes, mapped together as VIIe4. Tokoroa Forest, N75/420958 looking WSW.**

Fig. 108: **LUC subsuite 8c: VIIe4 and VIIIsl on ignimbrite cliffs in Waikato Valley. Maraetai Dam, N84/235783 looking NW.**

CHAPTER 6: CONCLUSION

FUTURE TRENDS AND CONSTRAINTS IN LAND USE

This section is a brief summary of the main trends and constraints in land use in the Bay of Plenty-Volcanic Plateau Region, as perceived by the author. It is by no means an attempt to construct a scenario for future land use; it is intended merely as a drawing together of the relevant parts of the "land use and land management" sections of each LUC suite in Chapter 5.

On arable land, especially in the Bay of Plenty, horticulture will continue to expand and diversify. Kiwifruit is expected to be the mainstay of this expansion. Between 1982 and 1987 a 62% increase in kiwifruit plantings has been projected, although, because of increases in other regions, the proportion of total New Zealand production coming from the Bay of Plenty-Volcanic Plateau Region will drop in this period from 62% to 52% (Kernohan & Sale 1983). There will also be diversification to other subtropical crops in the coastal Bay of Plenty, and to various fresh and process vegetable crops, pip fruit and berry crops in this district as well as elsewhere in the region, especially within the Rotorua-Taupo Graben. The southern Rangitaiki Plains-Taneatua districts will continue to be important maize cropping areas, but the potential for other cereal crops is difficult to predict. Overall, the Bay of Plenty will continue to be one of New Zealand's leading horticultural areas, and is likely to see the greatest increase in horticultural area of any region in New Zealand over the next 10 years (Fletcher 1984). Potential areas for horticultural development in the region have been identified and discussed in a recent agricultural planning report (Walker & Forsyth 1983). Their report emphasises the irrigation requirements for horticultural expansion, and is partly based on a series of county irrigation potential studies prepared by Water and Soil Directorate, Ministry of Works and Development, Hamilton.

Non-arable uses will also continue on arable land. Both dairying and sheep and cattle farming will continue as major land uses in districts where they are presently strongly established, but dairying, because it is concentrated on the most versatile LUC class I-III land, will face strong competition from horticulture. Various estimates have been made of the likely decline in total dairy production in the region due to horticultural expansion; these range from 10% to 30%. Exotic forestry will continue to be a significant land use on some arable land, especially on LUC class IV land with coarsely-textured infertile soils and cold winter climates. However, a survey of land use changes in the Northern Bay of Plenty indicated that less than 5% of the land changing from pastoral to forestry tenure between 1972 and 1982 was in LUC classes I-IV (Arthur-Worsop & Allan 1984).

On non-arable land there is considerable scope for intensification of pastoral use, particularly on more highly ranked LUC class VI units. There is little pastoral land in the region which is presently performing close to its attainable physical potential or even its 'top farmer' stock carrying capacity. The likely increase in the use of lucerne on both arable and non-arable land will be an important contributor to improved pastoral performance because of its high biomass production and drought tolerance. Lucerne will also be cultivated as a cash crop, but its overall expansion is subject to continued disease and pest resistance. Deer and goat farming will become increasingly important pastoral land uses.

On land with moderate to high exotic forestry potential, poorly-producing pastoral and undeveloped land will continue to be converted to exotic forestry. The continued expansion of exotic forestry, however, is unlikely to be as fast as it has been in the last 20 years; regional planting targets for the period 1981-1990 are about 44,000 ha (Working Party on Afforestation 1981). The forestry sector is closely planned and integrated, with published management plans for each state forest, as well as regional working plans for both public and private sectors.

The conversion of pastoral land to forestry is unlikely to be even over the whole region. The optimal balance between forestry and pastoral use has been a matter of contention for many years and will continue to be so in the forseeable future. Despite generally high exotic

forestry growth indices and favourable returns from forestry, a recent economic study in the northern Bay of Plenty (Arthur-Worsop & Allan 1984) has indicated that, with average farming management on presently developed pasture in most LUC class III-VI units, agriculture is more economic than forestry using a discount rate of 10%. For management at top farmer and potential stocking levels, agriculture is more economic than forestry on a wider range of sites, but on most LUC class VII land forestry was more economic. However, another recent study (Study Project Team 1983) examined the infra-structural and management implications of the continued expansion of the forestry industry. One of its suggestions was that the forestry sector "should shift from a tradition of extensive back-country estates on low fertility land, to smaller-scale, low tree-density forestry integrated with farming on better and more accessible sites".

The results of these two studies taken together indicate, firstly, that some of the more remote hill country is not particularly suited to either exotic forestry or agriculture, and secondly, that on the better land a major part of exotic forestry expansion is likely to be in the form of integrated forestry and farming systems. Indigenous forestry will further decline in relative importance as a land use, but some logging will continue, mainly on private land, and the region will continue to be an important source of North Island indigenous timber supplies.

The three main constraints to land use in the region are considered to be climate, the generally coarse-textured and phosphate-deficient soils, and the erodibility of unconsolidated soil parent materials. The climatic constraint generally increases from north to south through the region. The major factors of climatic limitation are cold frosty winters and soil moisture deficiencies in summer. The dry summers are especially serious because they not only limit biomass productivity but also make land more susceptible to grass grub infestation and to subsequent erosion caused by runoff over porous soils in which grass roots have been weakened. Steep terrain and low fertility soils also allow the spread of scrubweeds. Some of the above constraints are not so serious for forestry, because of the deeper root growth and greater soil-holding capacity of trees, but one constraint that is more serious for forestry than for pastoral use is the compacted nature of many subsoils.

NWASCO (1982) emphasised that the benefits and costs of soil conservation practices necessary to prevent erosion and maintain pastoral productivity may be the deciding factor in recommending exotic forestry or pastoral use as more suitable for a particular type of land. However, Healy (1967) has pointed out that the period of intense erosion which followed large-scale agricultural development in the 1950s and 1960s was possibly unprecedented for 1800 years (since immediately after the Taupo eruption), and that with careful management, active erosion phases in lowland areas are not necessarily recurrent.

Urban encroachment, often onto the most versatile yellow-brown loams or recent soils, is an increasing constraint to agricultural land use. Another related constraint is rapidly growing recreational and tourism-related land uses. There will be increasing competition between 'active' and 'passive' land uses, which may well put most pressure not on land but on water resources. Future irrigation requirements, the potential for ground water contamination by fertilisers and pesticides for agricultural use and by geothermal energy generation, possible conservation orders on major rivers, and the likely need for water for hydro-electric power and increased timber processing, are all factors which could put pressure on the region's water resources.

CONCLUDING REMARKS

One of the principal aims of this bulletin has been to show the dependence of land use capability in this region on various physical attributes of the land. These attributes vary in their importance in different parts of the region but the overriding importance of the type of tephra cover has been stressed throughout. Because each soil-forming tephra originates from a particular volcanic eruption or series of eruptions from a single source, the resulting land use capability suites are generally discrete geographical entities, i.e., they have a high degree of geographical continuity or unity. This is an important characteristic of the Bay

of Plenty-Volcanic Plateau Region, whereas in other regions the physical factor chosen to distinguish LUC suites may not be distributed in such a manner and the resulting LUC suites may therefore be scattered throughout the region. It is important to remember that, within the Bay of Plenty-Volcanic Plateau Region, other factors such as climate, relief, underlying rock type, etc., are super-imposed upon the differences in soil parent material determined by tephra cover. Even in this region, it would be possible to choose another factor on which to base land use capability suites. An obvious alternative to soil parent material would be climate (Blaschke, in press).

It is interesting to note that the region has changed within only 2 or 3 generations from one which was often described by Europeans as 'waste' or 'barren' to one in which development and diversification are rapid and competition for land is intensifying. The development of exotic forestry in the region has had much to do with this change. Since the initial development of this industry, the region has not only remained the most important in New Zealand for exotic forestry, but has also become the most important in the North Island for hydro-electric and geothermal energy resources and one of the most important horticultural regions in the country. It also remains an important region for pastoral farming, both for traditional sheep, cattle and dairy systems and for newer developments such as agroforestry and deer farming.

All these mainstays of the regional economy are clearly land-based. As they further intensify and diversify, the wise planning of land use, taking careful account of the inherent physical capabilities of the land, becomes just as important as careful and sustainable land management. Both planning and management must balance not only the uses mentioned above but also the 'passive' uses of watershed and water resource protection, recreation, and habitat conservation, all of which are also increasingly important economically. To this end, if this bulletin has aided an appreciation of the types of land in the region and their physical capabilities, it will have fulfilled its principal aim.

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APPENDIX 1

PUBLICATION DETAILS OF NZLRI WORKSHEETS IN THE REGION.

Worksheet & NZMS 1 sheet		*Author (s)**	*Date of field work**	*Date of publication*
Number	*Name*			
57 (pt)	**Te Aroha**	**K W Steel**	**1973, 1977**	**1978**
58	**Tauranga**	**K W Steel**	**1977**	**1978**
67	**Te Puke**	**A M Campbell**	**1977**	**1978**
68, 59	**Matata**	**P M Blaschke**	**1977**	**1978**
69 (pt)	**Whakatane**	**P M Blaschke**	**1977**	**1978**
74 (pt)	**Otorohanga**	**M R Jessen**	**1978**	**1979**
75 (pt)	**Arapuni**	**K W Steel**	**1977**	**1979**
76	**Rotorua**	**P M Blaschke**	**1978**	**1978**
77	**Tarawera**	**P M Blaschke**	**1977**	**1978**
78 (pt)	**Ruatoki**	**K W Steel**	**1978**	**1978**
83 (pt)	**Te Kuiti**	**M R Jessen** **P R Stephens**	**1976, 1977**	**1979**
84 (pt)	**Whakamaru**	**P R Stephens** **J C van Amerongen**	**1976, 1978**	**1979**
85	**Waiotapu**	**P M Blaschke**	**1978**	**1979**
86	**Galatea**	**A M Campbell** **P M Blaschke**	**1978**	**1978**
87 (pt)	**Waimana**	**K W Steel**	**1978**	**1978**
92 (pt)	**Ongarue**	**K-E Noble** **M J Page**	**1976**	**1979**
93 (pt)	**Waihaha**	**P R Stephens** **J C van Amerongen**	**1976, 1977,** **1978**	**1979**
94	**Taupo**	**A M Campbell**	**1977**	**1979**
95 (pt)	**Te Whaiti**	**P M Blaschke** **A M Campbell**	**1978**	**1979**
96 (pt)	**Maungapohatu**	**K W Steel**	**1978**	**1979**
102 (pt)	**Tokaanu**	**M R Jessen**	**1976**	**1979**
103 (pt)	**Rangitaiki**	**A M Campbell**	**1978**	**1979**
104 (pt)	**Maungitaniwha**	**A M Campbell** **P M Blaschke**	**1978**	**1979**
112 (pt)	**Ngauruhoe**	**A M Campbell** **M R Jessen**	**1976, 1978**	**1979**
113 (pt)	**Kaweka**	**A M Campbell**	**1978**	**1979**
122 (pt)	**Ruapehu**	**A M Campbell**	**1978**	**1979**

***Applies only to that part of worksheet within Bay of Plenty-Volcanic Plateau Region.**

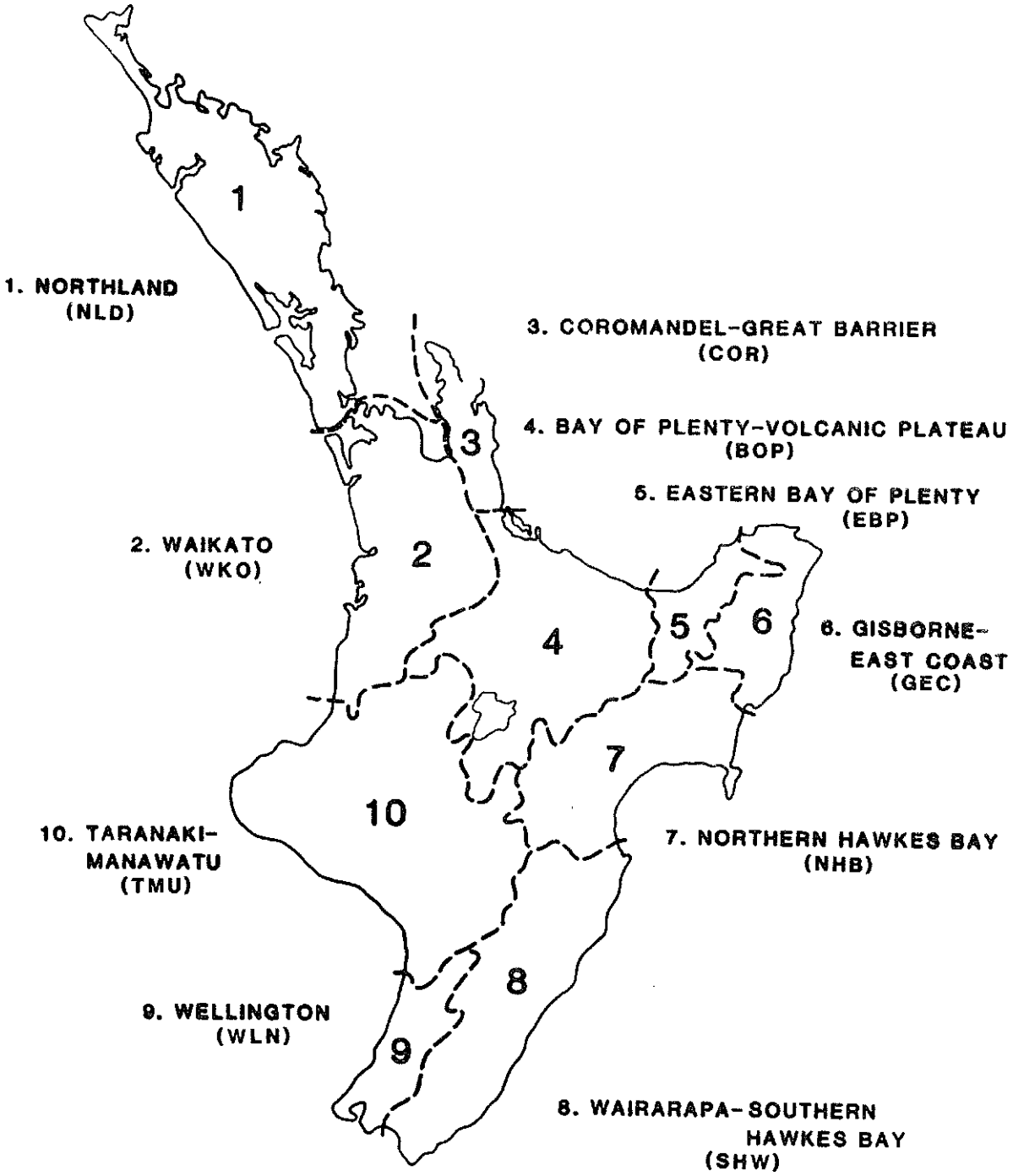
Note: **Bibliographic reference for individual worksheets (example):**

Steel, K.W. 1978: N58 Tauranga. NZ Land Resource Inventory Worksheet, National Water and Soil Conservation Organisation, Wellington.

APPENDIX 2

LAND USE CAPABILITY UNITS IN THE REGION AND CORRELATIONS TO OTHER REGIONS.

This appendix lists all the LUC units in the region, in the order in which they appear in the regional LUC extended legend (Steel 1979). As well as listing the area of each LUC unit, the LUC suite in which it has been placed in this bulletin (see Table 10, P. 34), and the page of the bulletin on which it is described, it gives the correlation of each LUC unit to its North Island Correlation Unit (N.I.C.U.), and, where applicable, to LUC units in adjoining regions. The correlation is from Page (1985). Some correlations are only partial (see Page 1985). See map below for location and number of adjoining regions.



Sig. 14'

LUC UNIT	*AREA (ha)*	*N.I.C.U.*	*REGIONAL CORRELATION*					*LUC SUITE*	*PAGE NO.*
			2	*3*	5	7	*10*		
			WKO	*COR*	*EBP*	*NHB*	*TMU*		
Iwl	**2,850**	**Nlw2**						**3**	**51**
Ilel	**3,400**	**N2el***		**Ilel**	**Ilel**			**1**	**40**
IIwl	**19,350**	**N2w2**			**IIwl**			**3**	**54**
IIsl	**9,500**	**N2sl**						**4a**	**67**
IIs2	**9,450**	**N2s2**						**3**	**54**
IIs3	**650**	**N2sl5**						**6b**	**102**
Illel	**4,350**	**N3el***		**Illel**	**Illel**			**1**	**40**
IIIe2	**10,200**	**N3e6**						**4a**	**67**
IIIe3	**850**	**N3el3**						**6b**	**102**
IIIe4	**12,800**	**N3el4**						**7a**	**122**
IIIe5	**5,750**	**N3el5**						**4b**	**78**
IIIe6	**6,950**	**N3e23**						**7b**	**128**
IIIe7	**8,700**	**N3e24**						**7d**	**142**
IIIe8	**1,450**	**N3e26**					**IIIe7**	**7c**	**135**
IIIe9	**6,400**	**N3e27**						**5**	**88**
IllelO	**6,100**	**N3e28**					**IIIe8**	**7f**	**155**
Illell	**12,300**	**N3e29**						**7h**	**174**
IIIel2	**6,350**	**N3e30**						**7f**	**158**
IIIwl	**15,250**	**N3w7**		**IIIwl**	**IIIwl**			**3**	**55**
IIIsl	**1,350**	**N3s7**						**7a**	**122**
IIIs2	**4,900**	**N3sl0**					**IIIs4**	**7b**	**128**
IIIs3	**4,600**	**N3sll**						**3**	**56**
IIIs4	**10,600**	**N3sl2**						**4b**	**76**
IIIs5	**4,500**	**N3sl3**						**6a**	**96**
IIIs6	**16,800**	**N3s20, N3s23**	**IIIsl**				**IIIs6**	**7f**	**158**
IIIs7	**2,650**	**N3s25**						**7h**	**174**
IIIcl	**2,150**	**N3cl**						**3**	**56**
IVel	**7,150**			**IVel**	**IVel**			**1**	**40**
IVe2	**8,650**	**N4e5**						**4a**	**67**
IVe3	**1,850**	**N4el0**						**6b**	**102**
IVe4	**34,300**	**N4el2**					**IVe5**	**7a**	**122**
IVe5	**8,350**	**N4el3**						**4b**	**78**
IVe6	**15,950**	**N4e25**					**IVe9**	**7b**	**130**
IVe7	**8,000**	**N4e26**						**7d**	**147**
IVe8	**19,050**	**N4e27**					**IVe9**	**7c**	**135**
IVe9	**23,200**	**N4e30**		**IVe2**				**5**	**88**
IVelO	**18,150**	**N4e31**						**7h**	**174**
I Veil	**1,400**	**N4e32**						**7b**	**130**
IVel 2	**11,900**	**N4e33**						**5**	**90**
IVel 3	**- 18,000**	**N4e35**					**I Veil**	**7g**	**168**
IVel 4	**1,400**	**N4e40**						**7g**	**169**
IVel 5	**5,800**	**N4e39**					**IVel 3**	**7f**	**158**

***Also includes LUC units from regions other than those listed.**

LUC UNIT	AREA (ha)	N.I.C.U.	REGIONAL CORRELATION					LUC SUITE	PAGE NO.
			2	3	5	7	10		
			WKO	COR	EBP	NHB	TMU		
Vcl	650	N5cl	Vcl					1	40
VIel	9,000	N6el		VIel				1	42
VIe2	6,850	N6e2*			VIel			1	42
VIe3	8,600	N6e7						4a	67
VIe4	12,900	N6e8						4a	69
VIe5	69,750	N6el9	VIe20				VIe9	7a	122
VIe6	32,150	N6e20						4c	82
VIe7	10,250	N6e34						6b	104
VIe8	6,700	N6e33						4b	78
VIe9	79,800	N6e40					Vie 18	7c	137
VIelO	37,000	N6e41						7c	137
VIell	45,650	N6e44		VIe4				5	90
Vie 12	17,100	N6e52						7h	176
VIel 3	6,050	N6e53						7d	144
Vlel4	10,850	N6e54						7d	144
Vie 15	28,250	N6e43						4b	79
Vie 16	9,650	N6e56						7c	137
Vie 17	11,200	N6e57						7b	130
Vie 18	2,500	N6e84			VIe4	VIell		8b	194
Vie 19	13,100	N6e79						7g	169
Vle20	30,650	N6e85						6a	97
Vle21	22,800	N6e87*			VIe5	Vie 12		8a	189
VIe22	16,400	N6e94				Vie 15		7i	181
VIe23	2,900	N6cl4					Vlc3	6c	109
VIe24	35,950	N6e95					VIe26	7f	159
VIwl	1,450	N6wl*	VIwl			VIwl		3	57
		N6w2*		VIwl		VIs2			
VIw2	1,750	N6w3					VIwl	7f	159
VIsl	24,150	N6sl					VIs2	7a	122
VIs2	33,700	N6s5					VIs5	7c	135
VIs3	2,800	N6s6						7d	144
VIs4	2,350	N6sl6*						2	47
VIel	3,150	N6cl2					VIc4	7e	150
Vllel	20,450	N7e8						4a	69
VIIe2	15,250	N7e9						4a	70
VIIe3	7,850	N7el5						6b	104
VIIe4	66,250	N7el6,						8c	197
		N7e35		VIIe3					
VIIe5	27,100	N7e28						4c	82
VIIe6	44,100 ■'	N7e31					VIIe8	7e	149
VIIe7	7,250	N7e32						7e	149
VIIe8	37,850	N7e39						6a	98
VIIe9	5,300	N7e33						4b	79
VllelO	126,150	N7e53*			Vllel, VIIe2	VIIe7		8a	189

***Also includes LUC units from regions other than those listed.**

APPENDIX 3

LUC UNIT	*AREA (ha)*	*NI.C.U.*	*REGIONAL CORRELATION*					*LUC SUITE*	*PAGE NO.*
			2	*3*	5	7	*10*		
			WKO	*COR*	*EBP*	*NHB*	*TMU*		
VIIIe3	**109,450**	**N8e6***	**VHIel, VIIe2**	**VIIIe3, VIIe8**	**VHIel**	**VIIIe5**	**VIIIe4**	**8a**	**190**
VIIIe4	**4,500**	**N8e7***		**VIIIe4**	**VIIIe2**	**VIIIe6**	**VIIIe7**	**8a**	**190**
VIIIe5	**9,750**	**N8e9, N8el2**					**VHIelO**	**6c**	**111**
VIIIe6	**7,400**	**N8ell***					**VIIIe8**	**8a**	**190**
VIIIe7	**8,000**	**N8el3***			**VIIIe4**	**VIIIe9**	**VIIIe9**	**8a**	**190**
VIIIwl	**2,950**	**N8wl**						**3**	**57**

***Also includes LUC units from regions other than those listed.**

SOIL SETS AND SERIES MAPPED IN THE REGION.

The following is a list of all soil sets and series recorded as dominant soils on worksheets covering the region. It also gives the soil survey or surveys in which each soil was recorded. Note that this list includes only soils recorded in the NZLRI, and not those mapped in subsequent soil surveys (i.e., it covers surveys 1-8 in Table 3, p. 23). Soil names refer to soil sets when used in survey 1 (NZ Soil Bureau 1954, referred to as 'General Survey' in text), and soil series when used in subsequent surveys (see p. 36).

Key to soil survey numbers

(Numbers and short names are the same as used in Table 3).

1. General Survey (NZ Soil Bureau 1954).
2. Taupo Survey (Rijkse in prep. a).
3. Whakatane Survey (Rijkse in prep. b).
4. King Country Survey (Rijkse & Wilde 1977).
5. Waiotapu Survey (Vucetich & Wells 1978).
6. Rotorua Survey (Rijkse 1979).
7. Kaingaroa Survey (Vucetich ***et al.*** 1960).
8. Piako Survey (Wilson 1980).

Soil set/series name	***Soil survey number***					
				4	***5***	***6***
Arahiwi						
Aroha	X		X			X
Atiamuri . .				X		
Awaiti						
Awakaponga						
Awakeri . .						
Benneydale				X		
Galatea ..		X		X	X	
Haparangi						
Haroharo. .	X					
Hauhungaroa		X		X		
Haumi			X			
Haupeehi..	X					
Hinemaiaia						
Hingarae . .		X				
Horomanga		X	X		X	
Huka			X			
Kaama						
Kaharoa ..	X					
Kaihere ..						X
Kaimanawa			X	X		
Kaingaroa	X				X	
Kairanga . .	X			X		
Katakati ..	X					
Kaweka ..	X		X			
Kawerau ..						
Kawhatiwhati					X	
Keepa						
Komata . .		X	X			
Kopeopeo						
Kopuriki . .				X		
Kuratau . .				X		
Mahorehore		X	X			
Makahoe ..		X				
Makerua . .	X	X				
Maketu	X		X			
		X				
		X				
	X			X		

APPENDIX 3

Soil set/series name	*Soil survey number*							
	1	2	*3*	*4*	*5*	*6*	*7*	*8*
Mamaku	X				X	X		
Manawahe	X		X					
Mangakahu				X				
Mangatepopo		X		X				
Mangorewa						X		
Mangowera	X							
Manunui				X				
Maraeroa	X							
Maroa		X			X			
Marsden	X							
Matahina			X		X	X		
Matawai			X					
Maungakakaramea					X			
Meeanee-Farndon	X							
Moeatoa	X			X				
Moerangi				X				
Mokai		X		X	X	X		
Mokau				X				
Motumoa		X		X				
Ngahewa					X			
Ngakuru		X		X	X	X		
Ngapouri					X			
Ngaroma	X			X				
Ngatiawa			X					
Ngauruhoe		X						
Ngongotaha						X		
Ohinepanea	X		X					
Okareka						X		
Okaro-Rotomahana					X			
Onepu			X					
Opiki	X							
Opouriao			X					
Oropi	X					X		
Oruanui		X	X	X	X	X		
Otakiri			X					
Otamatea		X						
Otamawairua				X				
Otanewainuku	X	X					X	
Oturere		X						
Oturoa						X		
Owawhenga				X				
Paengaroa	X							
Paretotara	X				X	X		
Paroa			X					
Pekepeke		X	X		X		X	
Pihanga		X		X				
Pinaki	X							

X

X

Piripai			**X**				
Pohaturoa					**X X**		
Pokaka					**X**		
Pongakawa	**X**		**X**				
Poronui			**X**				
Puaroa		**X**					
Pukawa					**X**		
Pukemaku	**X**		**X**				
Pukerimu		**X**	**X X**				
Puketui	**X**						
Rangipo	**X**	**X**			**X**		
Rangitaiki			**X X**				
Ratoroa	**X**						
Reporoa						**X**	

Soil set/series name	*Soil survey number*							
	1	2	*3*	*4*	*5*	*6*	*7 8*	
Rewatu			X					
Rotoaira		X						
Rotoiti	X					X		
Rotomahana	X				X X			
Ruakaka	X							
Ruakituri			X					
Takahiwai	X							
Tangatara	X							X
Tapuwae	X							
Tarawera	X		X		X			
Tauhara		X			X X			
Taupahi		X						
Taupo	X	X	X	X	X	X X		
Tawhia	X		X					
Te Kuiti				X				
Te Manaia	X							
Te Ngae						X		
Te Rahu			X					
Te Rangiita				X				
Te Rere					X X			
Te Teki			X					
Te Teko			X					
Te Tuhi								X
Tihia		X		X				
Tihoi		X		X	X	X		
Tikitere						X		
Timi				X				
Tokaanu		X		X				
Tokiaminga					X			
Tokoroa	X							
Turangi		X		X				
Urewera		X	X					
Utuhina						X		
Waihurua							X	
Waikaremoana			X					
Waikokomuka					X			
Waimangu					X			
Waimarino				X				
Waiotaka				X				
Waiotapu					X			
Waiowhiro						X		
Waipahihi		X		X X				
Waipunga	X							

APPENDIX 4

SELECTED CLIMATE DATA FOR THE REGION.

The following table presents selected climatic parameters for those climatological stations shown in Fig. 3a which have been nominated in the text as 'representative climate stations' for the various LUC suites and subsuites. All data are from summaries of observations of climatological stations to 1980 (NZ Meteorological Service 1983a), except for the data on frost-free days which are from Goulter (1981). Rainfall figures are in millimetres and temperature figures are in °C; other units are shown on the table.

Notes: a. J = January, F = February, M = March.

b. Figures shown for daily windrun (km/d) or hourly windspeed (km/h). Figures cannot be interconverted because of differences in instrument characteristics and exposure height.

c. Figures are means of period 1965-1975 only. Adjusted 30-year normals 1951—1980 give February mean rainfall as 80 mm.

d. Figures are means of period 1970-1980 only. Adjusted 30-year normals 1951-1980 give January mean rainfall of 81 mm, and annual mean rainfall of 1477mm.

e. Figures are means of period 1973-1980 only. Adjusted 30-year normals 1951-1980 give January mean rainfall of 113 mm, and annual mean rainfall of 1999 mm.

f. Recorded at Kawerau.

g. Recorded at Kinleith.

h. Recorded at Wairakei Power Station.

STATION DETAILS			RAINFALL		AIR TEMPERATURE			GROUND TEMP.	FROSTS			WIND	SUNSHINE
Name	Grid referciiC-jj	Alti tuuo (in)	Mean Annual	Lowest monthly mean*	No. of months <100 run	Mean Annual	Av. daily max. (warmest month)[3]	Av. daily min. (July)	Annual av. daily grass min	Average no. frost days July (ground)	Annual (ground')	Annual (air)	Ann. av. no frost-free days (air)	Mean wi ndrunk	Mean ann. Total hours
Atiamuri Power Stn	85/499732 | 95/170425	253	134U	F82	3	12.5	F24.4	1.4	5.1	14.8	53.0 | 131.8	38.8			
Minginui		366	1523	M91	1	11.4	J23.6	0.1	1.8	19.8		77.2	99	-	-
Murupara	86/141650 j 93/298453	198	1323	"91 F75	2	12.8	JF24.9	1.1	4.9	17.4	74.6	49.2	-	-	-
Otutira[0]	93/052585	579	1421		4	11.4	F22.0	3.2	-	16.6	62.3	6.7	-	-	-
Pureora Forest		549	1804	J106 !	0	10.5	JF20.9	1.2	3.1	15.8	86.9	48.4	147	-	-
Rotoehu Forest	68/970325	72	1641	J99	1	13.0	F23.5	2.3	5.3	11.9	44.0	28.9	250	127/d	-

1

J74

Rotorua Airfield	70/723019 | 76/7840/6	297	1429		4	12.9	JF23.3	3.0	3.9	13.2	72.1	19.1	220	-	1948[1]
Rotorua Airport		287	1491	J94 |	2	12.7	F23.0	3.0	5.3	13.3	56.9	21.2	254	12/h	-
Tarawera Forest	77/105053	61	2046		0	13.1	F24.9	1.2 i	4.2	17.5	84.9	53.9	-	-	-
Taupo	94/543386	376	1178	| M78 |	7	12.0	JF23.5	•1.9	4.1	15.9	71.4	37.1	187	211/d	2021
Tauranya[d]	58/642604 | 58/675609	2	1297	155	5	15.0	F23.5 !	6.6|	9.0	1.7 |	5.4	0	-	-	-
Tauranya Airport		4	1349	J91 |	4	14.0	F23.7	4.5	5.6	13.3	56.9 |	5.3	350	17/h	2277
Te Puke[e]	67/792429 j 77/260158	91	1754	J74 |	1	14.1	F24.1	4.8 |	5.1	13.9	63.2	4.8	-	-	-
Te Teko		8	1499	J90 |	2	14.2	JF25.4	3.7 |	6.1	12.9 |	45.9	10.0	287[f]	-	2177

Tokoroa	75/355947	305	1665	M94	2	12.4	F23.9	2.0 |	4.2 |	16.5	79.6	37.7	214[9]	-	-
				F8?											
Turangi	102/288001|	366	1586		1	12.0	F23.3	1.8 |	4.5]	15.1	70.8	37.9	-	-	-
Waimana	78/515025	37	1756	J113 |	0	13.6	J24.4	1.4 |	5.7 |	16.2	59.0 | 118.1	45.3	-	130/d	-
Waimihia Forest	103/73220^	743	1656	| M104 |	0	9.4	J20.3	0.1 |	1.9 |	18.9		72.2	93	-	-
				J98											
Waiotapu Forest	85/882829	435	1340		2	U.l	JF23.2	-0.1 |	2.7 |	19.3	108.2	78.7	157	-	-
Wairakei Res. Stn.	94/582463	402	1250	080 | H96	5	11.6	F23.6|	1.1	2.1 |	19.6	117.7	54.5	210[h]	103/d	-
Wairapukao	95/022559	437	1379		1	10.9	JF23.2	-0.8 |	2.2 j	20.6	120.3	88.6	105	-	-

Whakatane	69/407255	2	1323	J83	2	14.4	F24.1	4.1	7.3	5.4	15.3	4.4	334	-	2329

APPENDIX 5

EROSION ASSOCIATIONS OCCURRING IN THE REGION

The following table presents extracts from the legend to the series "Erosion Map of New Zealand". It names the 11 out of 21 nationally recognised erosion associations which occur in the Bay of Plenty-Volcanic Plateau Region, describes their key physical factors and most typical examples nationally, and gives the main locations of each association within the region. Because the first two columns are from a national classification, some features may not be strictly applicable to the region. For a simplified classification of 'erosion combinations' referring specifically to the region, refer to p. 27 in text.

Erosion symbol and association	*Key physical factors and typical New Zealand examples*	*Main areas in region*
B		
Frost heave, sheet and gully erosion. Minor debris avalanche, slip and scree creep erosion.	**Steep to very steep mountain ranges in Fiordland and North West Nelson. Sub alpine grasslands and herbfields on hard rocks, e.g., gneiss, diorite, granite, schist, and greywacke.**	**Central volcanoes, Kaimanawa tops, Kaimanawa and Kaimanawa Ranges.**
C		
Slip and debris avalanche erosion. Minor gully erosion on greywacke.	**Steep to very steep, forested montane slopes. Greywacke, schist, and other hard rocks.**	**Urewera and Kaimanawa Ruahine, ranges. Victoria, and Brunner Ranges.**
E		
Frost heave, wind, and sheet erosion leading to an erosion pavement.	**Flat to rolling slopes either intermontane basins or uplands.**	**Rangipo Desert, Mackenzie Basin, and the Rock and Pillar Range.**
G		
Sheet and scree creep erosion. Steep Minor slip erosion.	**hill country. Tararua foothills and Marlborough Sounds. Greywacke, schist, and other indurated rocks.**	**Parts of Urewera ranges.**
H		
Slip and sheet erosion.	**Steep hill country. Western Taumarunui, Inangahua valley. Indurated siltstones and conglomerates.**	**Steeper parts of Kaimai Range.**
P		
Sheet, wind and terracette formation. Gully erosion.	**Strongly rolling to steep hill country. Wairakei. Rhyolitic and recent ashes.**	**Most hill country throughout region. Ash-covered steeplands.**
Q		
Earth slip and slump erosion.	**Moderately steep to steep hill country. Taranaki (Ratapiko). Moderately to strongly weathered andesitic ashes, strongly and deeply weathered rocks.**	**Margins of Kaimai Range. Hill country around Tauranga Basin,**
R		
Wind and sheet erosion. Gully and tunnel gully erosion.	**Flat to undulating plains and terraces. Rangitaiki Plains, water-sorted Rhyolitic and recent ashes.**	**Most Taupo flow tephra and tephra surfaces.**

Erosion symbol and association	*Key physical factors and typical New Zealand examples*	*Main areas in region*
S		
Sheet and rill erosion. Minor gully erosion and wind erosion.	**Undulating to strongly rolling North Otago downlands. Pukekohe Hill.**	**Terraces around Tauranga Harbour.**
T		
Wind erosion and deposition	**Plains, terrace lands, and sand dunes. Canterbury Plains, Manawatu sand country. Semi-arid to subhumid to humid. Dune areas, various climates.**	**Bay of Plenty coastal areas, Galatea, Broadlands-Reporoa, and northern Kaingaroa Plains. Te Puke terrace country.**
U		
Negligible erosion to slight streambank erosion. Intermittent flooding and deposition.	**Lower terraces, floodplains and wetlands. West Coast, Hauraki Plains. Alluvial sediments with generally high water tables.**	**Bay of Plenty plains,**

APPENDIX 248
GLOSSARY OF PLANT NAMES

Currently accepted scientific names are given in this list for all common plant names used in the text (excluding crop or pasture species).

beech	***Nothofagus* spp.**
blackberry	***Rubus fruticosus***
bracken fern	***Pteridium esculentum***
bristle tussock	***Rytidosperma setifolium***
broom	***Cytisus* spp., commonly *C. scoparius***
danthonia	***Rytidosperma* spp.**
douglas fir	***Pseudotsuga menziesii***
eucalypt	***Eucalyptus* spp.**
fivefinger	***Pseudopanax arboreus***
flax	***Phormium tenax***
gorse	***Ulex europaeus***
hinau	***Elaeocarpus dentatus***
kamahi	***Weinmannia racemosa***
kanuka	***Leptospermum ericoides***
karamu	***Coprosma robusta, C. lucida***
kauri	***Agathis australis***
lupin	***Lupinus arboreus***
maire	***Nestegis* spp.**
mangrove	***Avicennia resinifera***
monoao	***Dracophyllum subulatum***
manuka	***Leptospermum scoparium***
marram grass	***Ammophila arenaria***
matai	***Prumnopitys taxifolia (Podocarpus spicatus)***
miro	***Prumnopitys (Podocarpus) ferrugineus***
mountain inaka	***Dracophyllum recurvum***
pampas grass	***Cortaderia jubata, C. selloana***
poplar	***Populus* spp.**
radiata pine	***Pinus radiata***
red tussock	***Chionochloa rubra***
rewarewa	***Knightia excels a***
rimu	***Dacrydium cupressinum***
rushes	**Juncaceae, esp. *Juncus* spp.**
short tussock	***Poa, Festuca, Rytidosperma* spp. etc.**
silver tussock	***Poa laevis***
snow tussock	***Chionochloa* spp.**
Spanish heath	***Erica lusitanica***
spinifex	***Spinifex hirsutus***
tawa	***Beilschmiedia tawa***
toetoe	***Cortaderia fulvida, C. toetoe***
totara	***Podocarpus totara***
tree ferns	***Dicksonia, Cyathea* spp.**
tutu	***Coriaria* spp., esp. *C. arborea***
umbrella fern	***Gleichenia cunninghamii***
willow	***Salix* spp.**
wire rush	***Empodisma minus***

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