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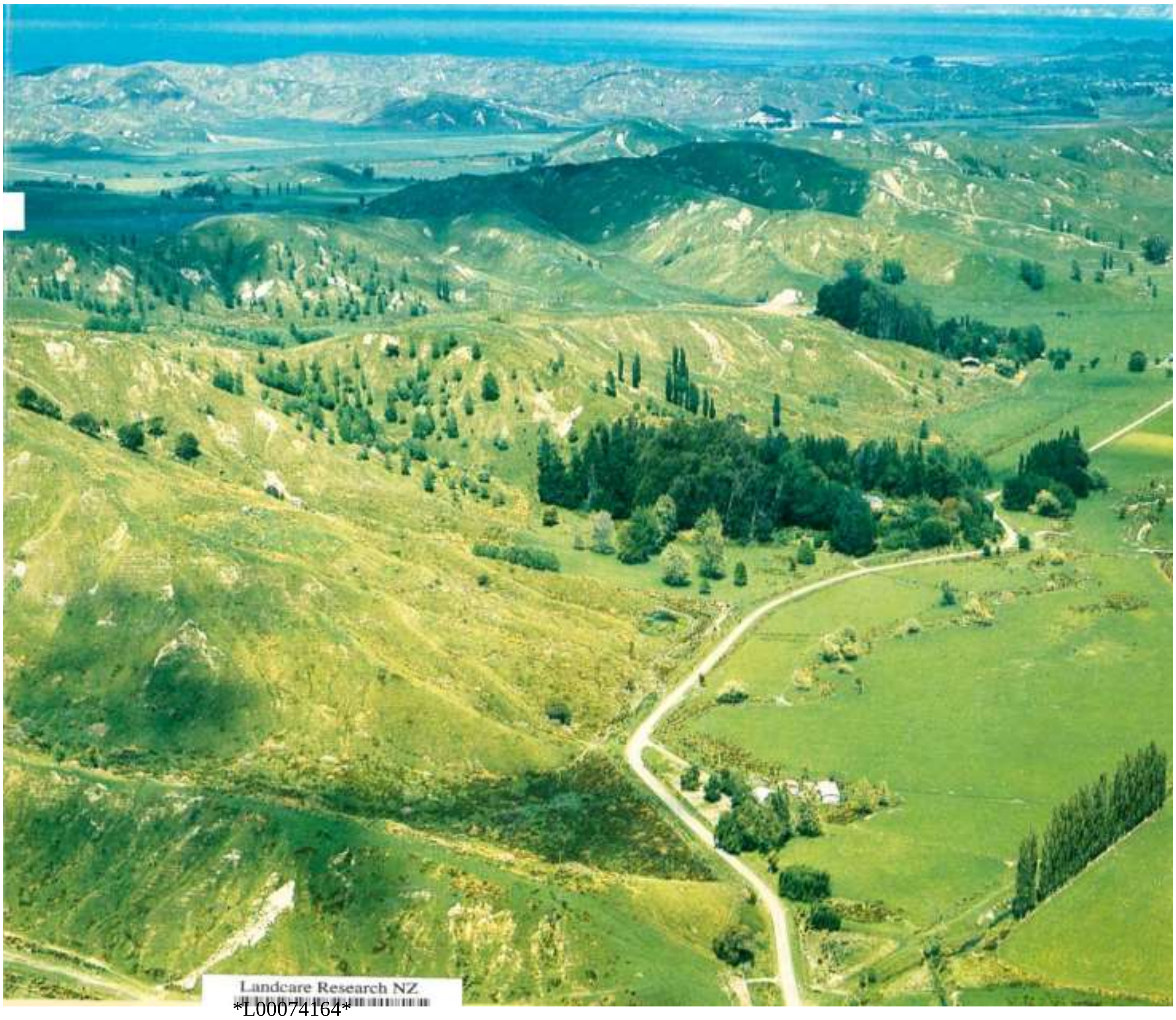
Land Use Capability Classification of the Northern Hawke's Bay Region



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Land Use Capability Classification of the Northern Hawke's Bay Region: a bulletin to accompany the New Zealand Land Resource Inventory Worksheets

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Land Use Capability Classification of the Northern Hawke's Bay Region: a bulletin to accompany the New Zealand Land Resource Inventory Worksheets

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This bulletin describes the land use capability classification and land resources of the Northern Hawke's Bay Region, an area of 1,151,780 ha on the east coast of the North Island, New Zealand. This Region is one of ten mapped in the North Island section of the New Zealand Land Resource 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 resource inventory and a land use capability (LUC) assessment at a scale of 1:63,360 (1 inch to 1 mile). The bulletin is intended for users of the LUC data.

The LUC classification for this Region contains 81 LUC units. These units have been arranged into 16 groups or "suites". An LUC suite is a grouping of LUC units, which, although differing in land use capability, share a definitive physical characteristic which unites them in the landscape. In this Region rock type is the most common basis for the grouping of LUC units into suites. Within LUC suites, LUC units are separated according to such features as slope, erosion potential, climate and wetness.

The bulletin provides a detailed description of each LUC suite, covering its climate, rock type and soil parent material, soils, topography, erosion, vegetation, land use and land management. The LUC units within each LUC suite are also described and illustrated by photographs. Also included is a general regional description and a summary of physical resource factors.

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COVER: Coastal hills (LUC unit VIe7) and alluvial plains (LUC unit IIIwl), 6 km east of Wairoa (Waiatai Valley in foreground).
Photo: Noel Trustrum

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INTRODUCTION

This bulletin is one of a series accompanying the New Zealand Land Resource Inventory (NZLRI). The purpose of the bulletin is to explain the basis of the land use capability classification of the Northern Hawke's Bay Region, and to describe in detail the land use capability (LUC) units.

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 programme LADEDA (van Berkel and Eyles 1981). The NZLRI has been prepared 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 research centres in Palmerston North and Christchurch.

Tw"> 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 evaluation of the long-term potential for sustained production, in the form of a land use capability assessment.

   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 1971) and in NWASCO (1979).

The Northern Hawke's Bay Region is one of ten North Island land resource survey regions (Figure 1), each with its own land use capability classification. For each region the land use capability units have been summarised in an extended legend.

Extended legends for Regions adjacent to the Northern Hawke's Bay Region have been compiled by Driver (1974), Page (1975), Noble (1979), Steel (1980) and Fletcher (1981). A correlation of land use capability units in all ten North Island NZLRI regions has recently been prepared (Page 1985).

Field work in the Northern Hawke's Bay Region began in 1974 and was completed in 1977. The Region is covered by all or part of 19 worksheets (Figure 2). Appendix 6 lists these worksheets together with names of authors and dates of field work. Survey numbers of aerial photographs used in the compilation of the NZLRI worksheets is given in Appendix 7. The regional LUC classification and extended legend were prepared by M J Page (1976a).

In describing the land use capability classification this bulletin emphasises the relationships between different LUC units by grouping related units into "suites". The main part of the bulletin describes each land use capability suite and its constituent LUC units. The description of each suite emphasises the similarities between LUC units, while the descriptions of the LUC units themselves emphasise the differences. This is preceded by a description of the Region and a summary of its physical resource factors. The bulletin is not intended to be an exhaustive resource document for the Region, rather it describes the physical resources in terms of land use capability. Three earlier publications describing both the physical and social resources of the Region are "The land utilisation survey of the Gisborne-East Coast Region" (Department of Lands and Survey 1964), "Hawke's Bay Region" (National Resources Survey 1971) and "East Coast Regional Resources Assessment" (Ministry of Works and Development 1979). Readers are referred to other literature referenced in the text for more detailed resource information.

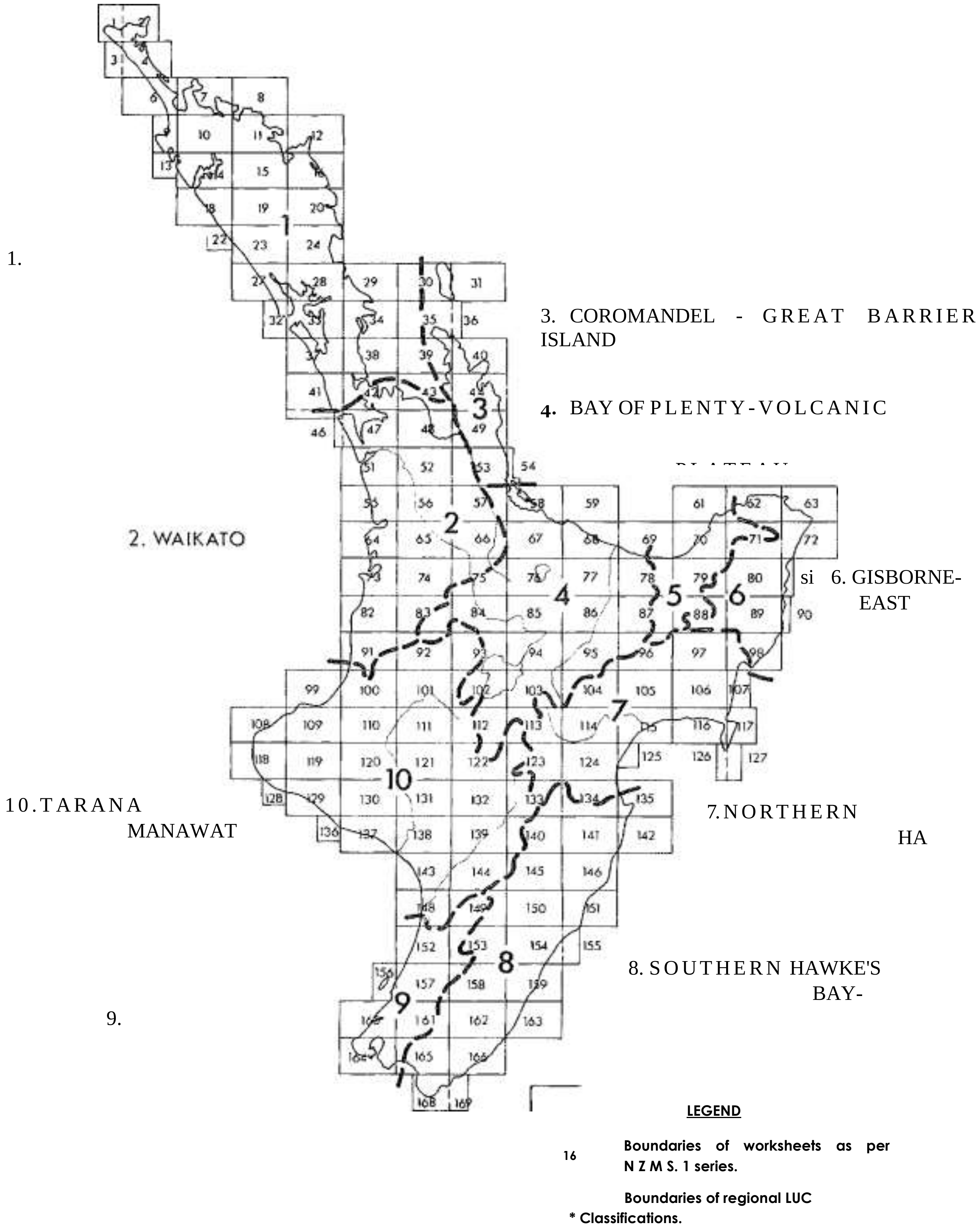


Figure 1: North Island NZLRI Regions.

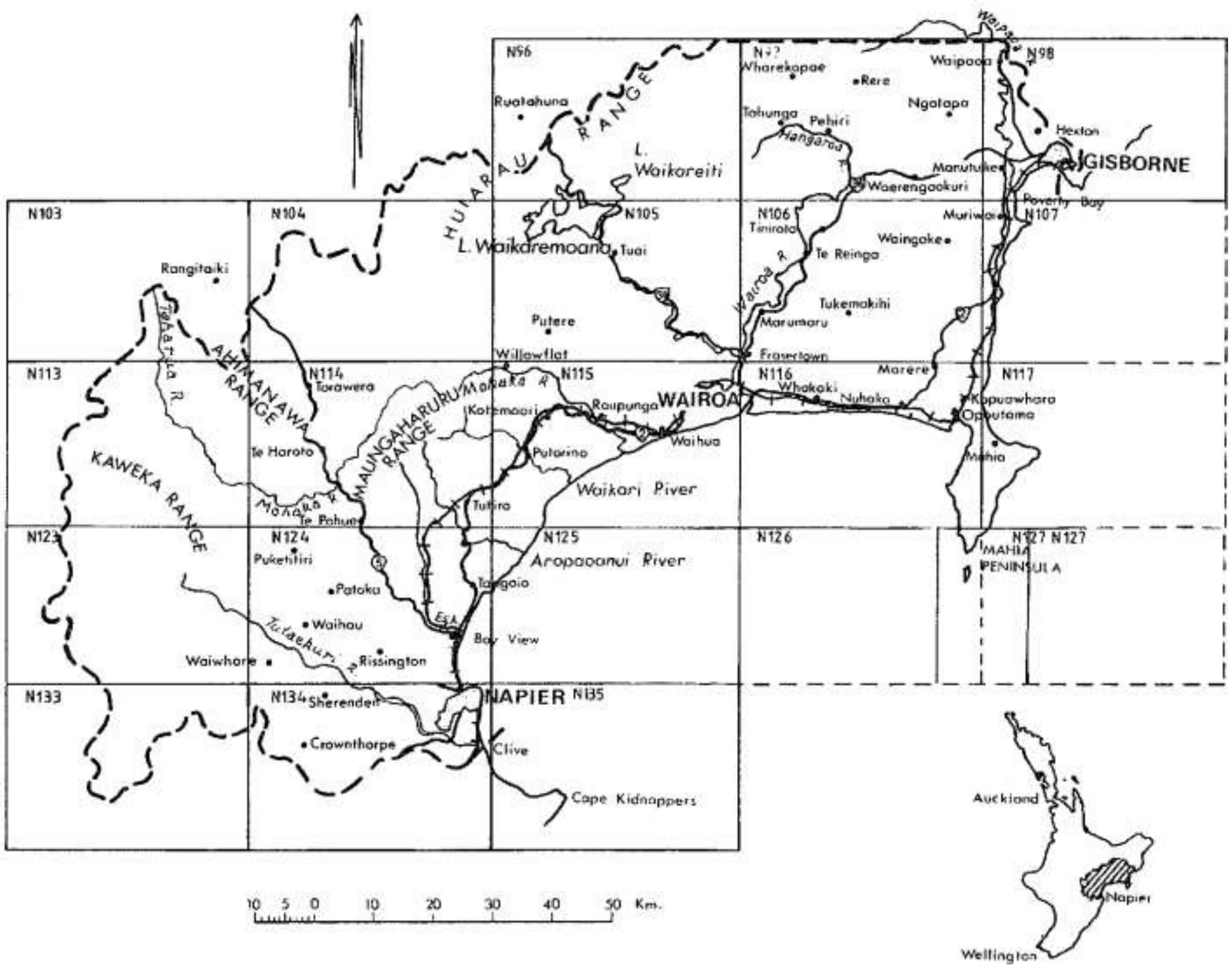


Figure 2: Location of Northern Hawke's Bay Region, showing main physical features and position of NZLRI worksheets. Regional boundary is shown in heavy dashed line.

THE NORTHERN HAWKE'S BAY **REGION**

LOCATION AND BOUNDARIES

The Northern Hawke's Bay Region, as delineated in the NZLRI, has an area of 1,151,780 hectares and is located on the east coast of the North Island (Figure 2). Although the Region is centered on Northern Hawke's Bay, it also extends north as far as Gisborne and south to include part of central Hawke's Bay.

The regional boundary follows the eastern margin of the Gisborne Plains from Gisborne to Te Karaka. From there it runs west along the southern margin of NZMS1 Topographical Series Sheet N88, and then follows the main divide between the Hawke's Bay and Bay of Plenty catchments. It continues south along the catchment boundary defining the headwaters of the Taruarau and Ikawetea Rivers and then follows the course of the Ngaruroro River to the coast between Napier and Hastings.

PHYSIOGRAPHY

The physiography of the Region is controlled largely by rock type and geological structure. Within this setting climatic forces, mainly through the agent of erosion and subsequent deposition, have given rise to the present landforms.

Much of the Region is relatively young in a geological sense. Most of the rocks are of late Tertiary and Quaternary age (less than 20 million years). The oldest rocks are Mesozoic in age (70-230 million years) and are confined to the main ranges. Northern Hawke's Bay is part of the 'East Coast Deformed Belt' (Sporli 1980), and as such is tectonically active. Faults are common throughout the area. Principal faults such as the Ngamatea, Kaweka, Ruahine, Mohaka and Waikaremoana Faults have major topographic expression, defining such features as mountain ranges, basins and valley systems. The area has been, and still is, subject to tilting and uplift with subsequent downcutting by rivers and streams. Major structural features of the Region are the Wairoa Syncline and the Hawke's Bay Syncline (Grindley 1960).

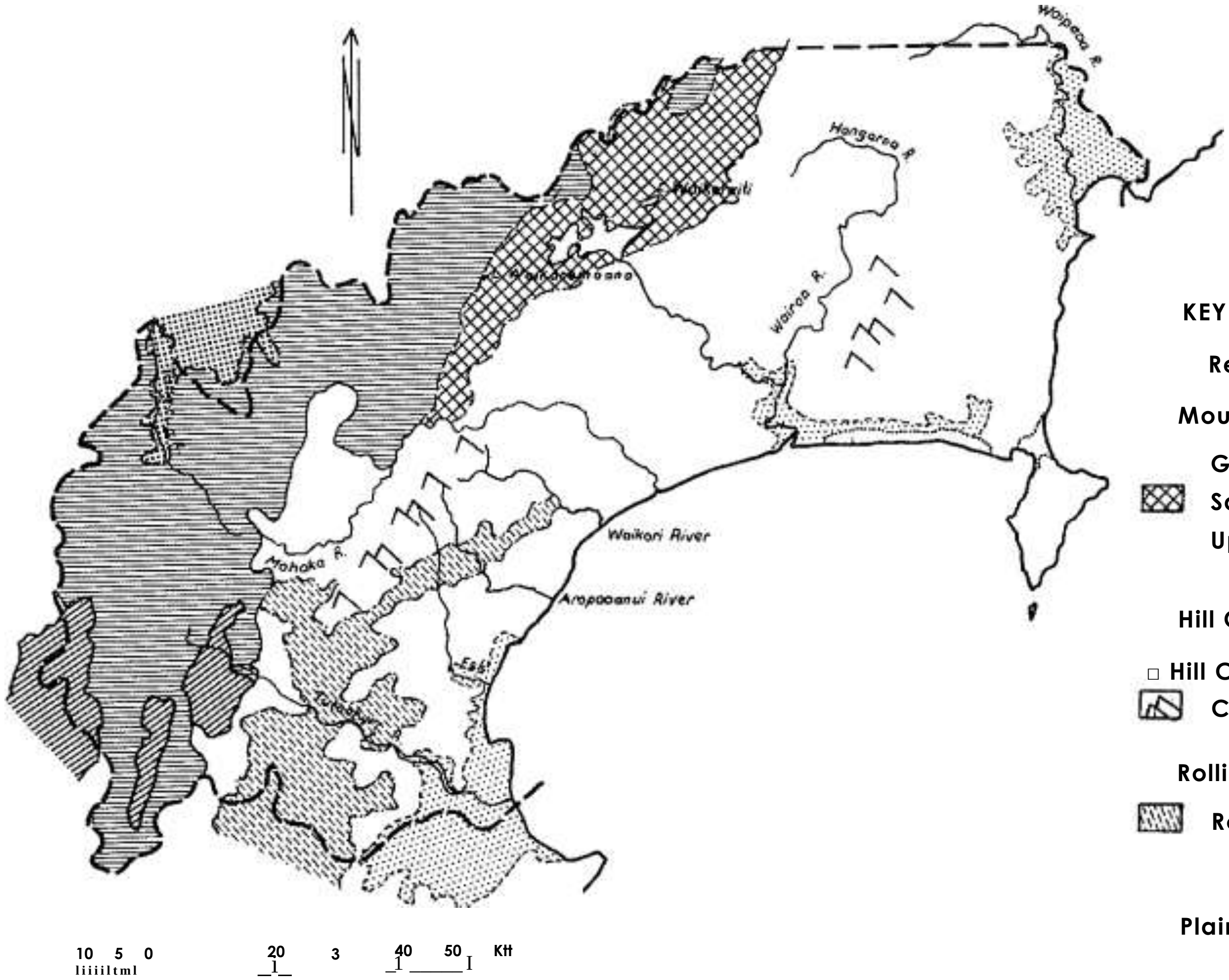
Within the Northern Hawke's Bay Region four broad physiographic zones can be identified (Figure 3). As with the whole east coast of the North Island there is a pronounced north-east south-west structural alignment which affects major landforms. An account of Hawke's Bay landforms in terms of their geological origins is given in Kamp (1982).

The four physiographic zones are:

1. **Mountain Ranges:** These occur in the west of the Region and are part of the axial ranges which extend throughout the length of the South Island and most of the North Island. Although the zone consists of a continuous belt of mountains, a number of distinctive ranges can be recognised. They are from north to south, the Huiarau, Ahimanawa, Kaweka and northern Ruahine Ranges. To the west of the Kaweka Range is the margin of the Kaimanawa Ranges. Except in the case of the Kaweka Range only part of these ranges are in the Northern Hawke's Bay Region.

   These ranges are very steep and rugged, rising to over 1500 m a.s.l. in a number of places and reaching 1724 m on the Kaweka Range. The majority of these ranges are composed of Mesozoic greywacke, although in the north of the area around Lake Waikaremoana the rocks consist of Tertiary sandstones and siltstones. Likewise in the south between the Ruahine and Kaweka Ranges there are several plateaux and basins of Tertiary sediments.

2. **Hill Country:** This is the largest zone in the Region and extends from the axial ranges to the coast. The hills are generally moderately steep to steep, but also include small areas of rolling downland and numerous narrow valley systems with alluvial terraces. The north-east south-west alignment of topography is particularly apparent in this zone. The most prominent features are the Maungaharuru and Te Waka Ranges and Whakapunake. Each has a steep scarp slope and a long dip slope. Other prominent ridges or cuestas occur near Lake Waikaremoana where they extend into the mountain



KEY

Regional Boundary

Mountain Ranges

Greywacke Ranges

Sandstone, Mudstone Ranges

Upland Plateaux and Basins

Hill Country

Hill Country

Cuetas

Rolling Downland

Rolling Downland

Plains and Terraces

Alluvial Plains and Terraces

Volcanic Plains and Terraces

Sand Dunes

Figure 3: Major physiographic zones in the Northern Hawke's Bay Region.

ranges zone. Rock types in the hill country zone are Tertiary and early Quaternary mudstones, siltstones, sandstones, limestones and conglomerates.

3. Rolling Downland: In the south of the Region between the mountain ranges and the Heretaunga Plains, the hill country is less steep. Here there is a strip of rolling to strongly rolling downland which extends north towards Kotemaori.
4. Plains and Terraces: There are three major alluvial plains in the Region, each along the lower reaches of a major river system. They are, the Heretaunga Plains north of the Ngaruroro River near Napier, the Wairoa Plains along the Wairoa River and the Gisborne Plains along the Waipaoa River. A narrow coastal terrace runs from the Wairoa Plains to Nuhaka, and is bordered on the seaward side by a strip of sand dunes. Sand dunes also join Mahia Peninsula to the mainland. Narrow volcanic plains and terraces occur at the heads of several rivers on the north-western boundary of the Region. These plains and terraces are extensions of the Rangitaiki Plains.

During the last 20,000 years a number of tephras have been deposited in the Northern Hawke's Bay Region. Although some of these reached the coast, tephra is generally shallow to absent in the east and thicker in the west towards the sources of origin. There are three such sources: the Okataina, Taupo and Tongariro Volcanic Centres. Although originally tephra was deposited over the whole Region, much has been removed by erosion. Today it is absent from most of the steeper slopes, and from recent depositional landforms such as alluvial plains and sand dunes which have formed since the tephra was deposited. Tephra may however be present in alluvial deposits, having been eroded from other landforms and carried by rivers, along with their other sediments, to form plains and terraces.

In the south of the Region landforms have been mantled by a deposit of a different sort. This is loess, an accumulation of fine windblown particles, originating from nearby rivers. The time of greatest deposition was during the last glaciation when, with cooler temperatures and less vegetation, rivers were carrying higher sediment loads resulting from increased erosion.

The Region has a number of major rivers. The northern part of the Region is drained by the Waipaoa River which flows into Poverty Bay. The other major rivers all flow into Hawke Bay. They are, from north to south, Nuhaka, Wairoa, Waihua, Mohaka, Waikari, Aropaoanui, Esk, Tutaekuri and most of the Ngaruroro River. The largest are the Wairoa, Mohaka and Ngaruroro, all of which have a number of significant tributaries. In the southern and central part of the Region major rivers are deeply incised in their middle reaches, and in the case of the Mohaka and Waikari Rivers they are incised all the way to the coast, emerging between cliffs. These incised rivers have a series of high terraces formed during a period of relative stability in the late Pleistocene, after which uplift (which is continuing today) has caused downcutting of these rivers to their present level.

Several lakes occur within the Region, the largest being Lake Waikaremoana in the Urewera National Park. Another smaller lake, Waikareiti occurs nearby. Lake Tutira is situated in hill country north of Napier. A number of other smaller lakes are scattered throughout the Region. Most of these have been formed by landslides that have blocked the course of rivers and streams.

The Region has a varied coastline. Old Napier prior to the 1931 earthquake was built on Scinde Island, a hill of siltstone and limestone that was largely surrounded by the Ahuriri Lagoon. At the time of the earthquake Ahuriri Lagoon and the area around Meeanee were uplifted approximately 1.5 m so that today the area consists of sands, silts and muds separated from the sea by a gravel ridge. From Tangoio Bluff to Wairoa the coastline consists of cliffs, in places up to 400 m high. The area between Wairoa and Nuhaka is a coastal plain comprising a narrow belt of sand dunes and sand plains behind which lies a narrow alluvial plain and a series of small lagoons. The coastline between Nuhaka and the Gisborne Plains is a series of steep hills and cliffs, the most prominent of which is Young Nick's Head at the southern end of the Gisborne Plains. A narrow strip of sand dunes separates the Gisborne Plains from the sea.

Southeast of Nukaka is Mahia Peninsula which is connected to the mainland by a tombolo, consisting of a narrow neck of sand dunes. Mahia Peninsula consists of steep hills terminating in coastal cliffs, with areas of raised marine terraces in the north-east and south-west. Off the southern tip of the peninsula lies Portland Island, a terrace remnant.

CULTURAL FEATURES

Although the Northern Hawke's Bay Region covers 10% of the North Island it has only three significant population centres. These are Napier (1982 population 48,600), Gisborne (30,100) and Wairoa (5,430). All three are coastal centres with Gisborne being situated in the extreme north of the Region, Napier in the extreme south and Wairoa in the centre. Inland areas of the Region are practically devoid of even small rural towns. Consequently much of the Region is quite isolated and, in the case of the westernmost mountainlands, unoccupied.

The Region has several major highways. State highway 2 runs from Napier through Wairoa to Gisborne and state highway 5. the "Napier-Taupo Road", links Hawke's Bay with the central North Island. Provincial highway 36 provides an alternative inland route between Wairoa and Gisborne (via Tiniroto), and provincial highway 38 links Wairoa and Rotorua via Waikaremoana. The Region is further serviced by numerous county roads one of which, the "Napier-Taihape (Gentle Annie) Road", provides another link with the central North Island. The axial ranges in the west of the Region provide a significant barrier between Hawke's Bay and the central North Island. They are crossed by road in only three places, by state highway 5, provincial highway 38 and the Gentle Annie Road, in each case at a relatively low point in the ranges. Of these only state highway 5 is a major route.

A rail link exists between Napier and Gisborne which follows closely the route of state highway 2. Airports are situated at Napier and Gisborne, and an airfield at Wairoa. Napier and Gisborne each has a small port which exports agricultural, horticultural and forestry products, and is also the centre for a local fishing industry. With the increase in forestry throughout the east coast, port activity is expected to increase. Wairoa and Waikokopu are the sites of minor ports which are no longer used.

Administratively the Region is covered by six counties. They are Wairoa County, most of Hawke's Bay County and smaller areas of Cook, Taupo, Rangitikei and Waikohu Counties. Two catchment authorities are responsible for water and soil conservation within the Region. The Hawke's Bay Catchment Board covers most of the Region and the East Cape Catchment Board covers the Gisborne Plains and a small area of hills to the west and south.

LAND USE

The original indigenous vegetation over much of the Region was forest, with tussock and sub-alpine scrub at higher altitudes in the western ranges. Small areas of swamp and scrub occurred on the plains and coastal sands. During pre-European Maori occupation significant areas were modified, especially near the coast where major populations occurred, and along inland routes. At the time of European settlement the Maoris had cleared parts of the Heretaunga, Wairoa and Gisborne Plains and were growing crops. In addition a significant part of the dry coastal hill country had been burnt, either intentionally or by accident, and was covered in manuka and bracken. Guthrie-Smith (1953) describes this fire induced vegetation occurring as far inland as Lake Tutira, where blackened stumps of a former forest stood. An area along the route of the Napier-Taihape Road south of the Kaweka Range also appears to have been repeatedly burnt prior to European settlement.

European settlement began in the 1830s with whalers and missionaries. In the 1850s farming commenced, initially on the fertile plains and the coastal hill country. The scrub and fern covered hills were easier to convert to pasture than the forests further inland, and were also more accessible to the major settlements. As the demand for land increased, clearance of the forested inland areas began. Many areas of forest were milled before being burnt, although this was not always the case. Initially pastoral farming consisted of extensive holdings with large flocks of sheep. There were few fences and little stock management.

Together with scrub and forest clearance, control of reversion was a major activity. Over the years these large sheep stations have been subdivided and most of the scrub and forest of the hill country has been cleared. Today pastoral farming is more intensive and is based on sheep and cattle, with recent diversification into goats and deer (Advisory Services Division Gisborne 1979, Crawford 1981).

Fourteen Lands and Survey farm settlements are located within the Region. Until 1977 there were also two soil conservation reserves in the Region, at Tangoio and Waerengaokuri. The history of these reserves is described by McCaskill (1973). The Waerengaokuri reserve is now partly used as a nursery for the East Cape Catchment Board, with the remainder having a continuing erosion control function. The area at Tangoio is now the Tangoio State Forest.

Although the fertile alluvial plains at Napier, Wairoa and Gisborne were originally used for sheep farming and grain crops, the potential for more intensive uses was soon recognised. Initially development was hindered by flooding and poor drainage. Nevertheless, orcharding began near Napier in the 1890s. Today orchards and vineyards occupy much of the better land on the plains at Napier and Gisborne. A wide variety of horticultural crops are also grown and there has been a recent trend to subtropical fruit, particularly kiwifruit (Advisory Services Division Gisborne 1982, Glenny 1982). Maize is still a major crop particularly near Gisborne, but less of this highly productive land is now used for pastoral farming.

Exotic forestry in the Northern Hawke's Bay Region began in 1949 at Patunamu State Forest north-west of Wairoa. In the next 15 years Esk, Mohaka, Wharerata and Kaweka State Forests were established. Today there are 9 exotic state forests in the Region with the recent additions of Woodstock, Raupunga, Awahohonu and Tangoio State Forests. Small parts of three central North Island exotic state forests (Waimihia, Kaingaroa and Waipunga) also occur on the western margin of the Region. In recent years there has also been an increase in private forest planting, especially in the area north of Napier.

A number of major processing plants, sited mainly in the areas around Gisborne and Napier, handle the agricultural, horticultural and forestry products from the Region. Gisborne has two freezing works, one cannery and three wineries. Three freezing works are situated between Napier and Hastings (just beyond the regional boundary). Likewise three canneries and eight wineries are situated on the Heretaunga Plains. A further freezing works is located at Wairoa. A pulp and saw mill is located at Whirinaki 12 kms north of Napier. Napier also has a fertiliser works.

Undeveloped land is mainly restricted to the mountain ranges in the west. The bulk of this is forest with small areas of scrub and tussock. The area around Lake Waikaremoana is within the Urewera National Park, while the ranges further south contain the Kaweka State Forest Park and small portions of the Ruahine and Kaimanawa State Forest Parks. A number of indigenous state forests occur in the mountain ranges and in the hill country. The remainder of the mountain ranges consists of crown, Maori or private land. Undeveloped land within the hill country is limited with only small remnants of forest, usually cutover. Many of these are scenic reserves. A brief description and history of many of these reserves, and other areas popular for outdoor recreation are given by Cunningham (1983). Scrub is somewhat more common, as established blocks or often scattered among pasture. Manuka or mixed indigenous scrub are the major scrub types. Exotic scrub is less significant in this Region and is usually found within pasture, the main species being gorse and blackberry. Small areas of wetlands and sand dune vegetation occur along the coastline. Significant areas of scrub have been cleared in the last few years as a result of the Land Development Encouragement Loan Scheme.

PHYSICAL RESOURCE FACTORS

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 degree and type, and vegetation cover. The standard layout of the inventory code is:

Rock type—Soil unit—Slope group

Erosion degree 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 map unit 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 Northern Hawke's Bay Region is 178 ha, although map units down to a minimum size of approximately 20 ha are recorded. Further information on general aspects, and interpretation of the NZLRI is available in Howard and Eyles (1979), in "Land Use Capability Survey Handbook" (Soil Conservation and Rivers Control Council 1971) and in "Our Land Resources" (National Water and Soil Conservation Organisation 1979).

This section 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 will be given in the section on LUC suites.

CLIMATE

Although climate is not one of the five factors in the inventory code it is nevertheless an important resource factor in assessing land use capability.

There are eighteen climatological stations in the Northern Hawke's Bay Region (Figure 4); these tend to be in the more densely populated lowland, coastal areas, with few stations in the hill country or mountain areas. Consequently extrapolation of records in these areas is less reliable. Rainfall records are somewhat more detailed as rain gauges are more numerous.

Major sources of climatic information used in the survey were: the 1:500,000 isohyet map of New Zealand (New Zealand Meteorological Service 1978), records of rainfall normals (New Zealand Meteorological Service 1984), climatological records from individual stations (New Zealand Meteorological Service 1983a), de Lisle and Patterson (1971) and Kerr *et al.* (1981).

Located on the east coast, the Northern Hawke's Bay Region is largely sheltered by the axial ranges from the prevailing westerly weather systems which affect New Zealand. Consequently the Region is generally drier, sunnier and less windy than areas on the west coast. However a component of the weather pattern is the erratic occurrence of cyclonic storms from the east. A feature of the weather, therefore, is its degree of variability. Droughts of up to 5 months may occur, and although annual rainfall is not high, rainstorms of high intensity may occur at any time of the year. Some of the highest recorded rainfall intensities in New Zealand have been recorded within the Northern Hawke's Bay Region.

Within the Region climatic conditions vary considerably and are mildest near the coast. With increasing altitude and distance inland conditions become more severe. Five climatic types as defined by New Zealand Meteorological Service (1983b) occur within the Northern Hawke's Bay Region (Figure 4). The majority of the coastal areas between Napier and Gisborne are type CI where summers are very warm and dry and winter temperatures are moderate. Annual rainfall is between 1000-1500 mm. The driest area, type C2, occurs in the south near Napier where annual rainfall is 800-1000 mm and summer droughts are common.

Type C3 occurs further inland than C1 where it is cooler and annual rainfall is 1500-2500 mm. In the main ranges the climate is type M, a high rainfall mountain climate with strong winds and colder temperatures. Beyond the ranges on the edge of the Rangitaiki Plains the climate type is B2. Here conditions are more sheltered with warm summers and cool winters with frequent ground frosts. Annual rainfall is approx. 2000 mm.

The rainfall range for the Region is 800-3000 mm p.a., with the majority of the Region receiving 1200-2000 mm (Table 1). Rain days per year are as low as 120-130 near Napier, rising to 180-190 in the hill country. Although heavy falls may occur throughout the year there is generally a winter maximum and a spring or summer minimum. The effect of these low spring and summer rainfalls on soil moisture reserves is accentuated by the drying effects of warm fohn winds (Figure 5).

Table 1: Distribution of rainfall categories in the Northern Hawke's Bay Region

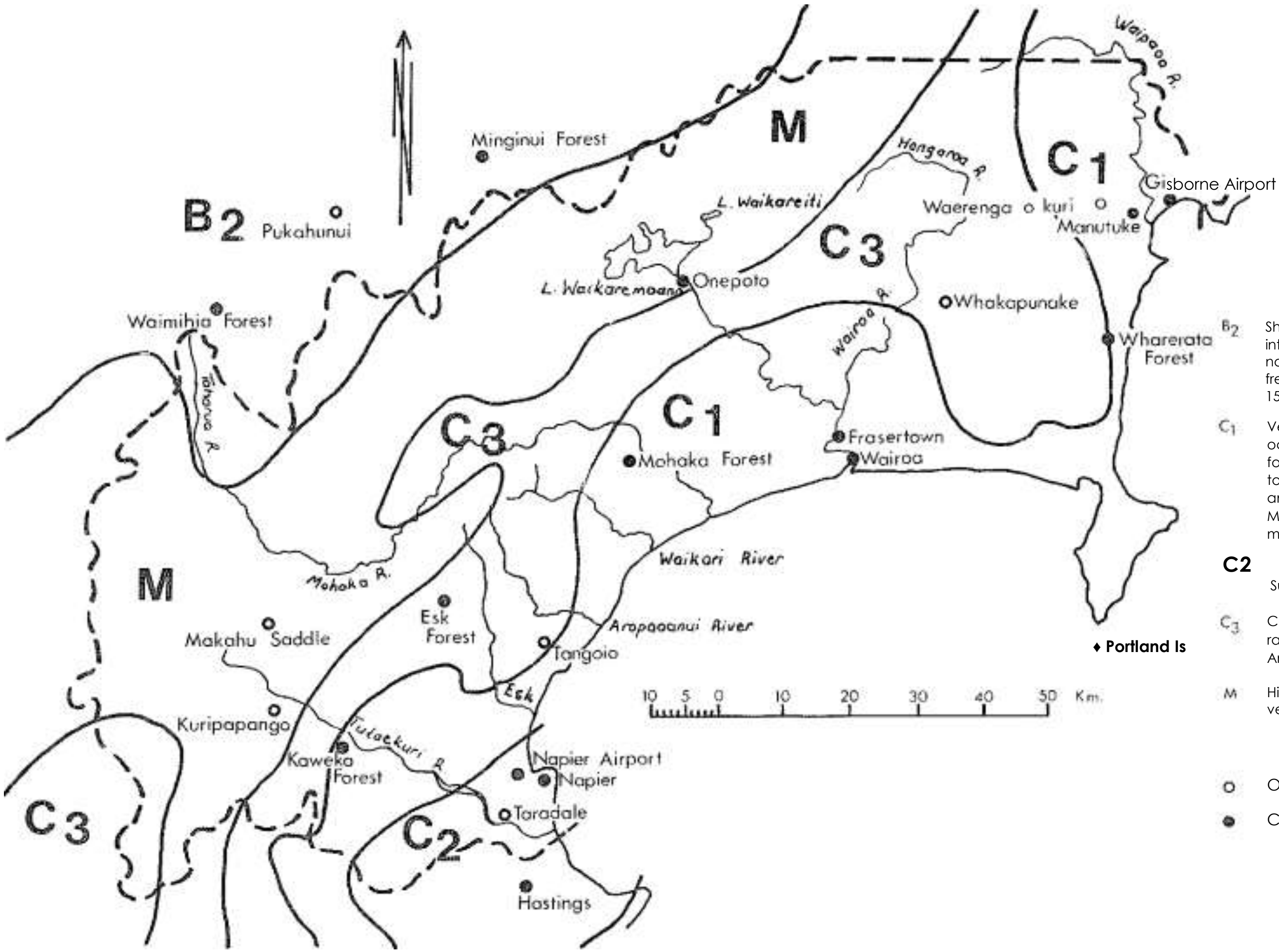
Annual Rainfall	Area	Percentage
<1200 mm	168,640 ha	14.6%
1200-2000 mm	652,860 ha	56.7%
>2000 mm	330,280 ha	28.7%
TOTAL	1,151,780 ha	

Temperatures are highest near the coast and decrease with increasing altitude and distance inland. Lowland temperatures above 25C are frequent in summer and may exceed 32C. Frosts occur throughout the Region. Although not common on the major plains, frosts can affect susceptible crops.

ROCK TYPE

Rock types were recorded for each map unit, using the NZLRI North Island Rock Type Classification (Crippen and Eyles 1985). The classification is listed in Appendix 11. This classification is designed specifically for soil conservation purposes and groups together rocks and lithological types with similar erosion susceptibilities. In the NZLRI the rock type factor is used to record basement rock and any cover deposit such as tephra. Only those rock types that directly influence surface morphology and land use are recorded. In the case of cover deposits a maximum of three rock types are recorded, in stratigraphic order. Hence in some cases a rock type may be present which does not appear in the inventory. A maximum of two surface rock types are recorded per map unit.

A variety of geological information was used to assist in the mapping of rock types. The major source was the NZ Geological Survey 1:250,000 Geological Map of New Zealand series. The Region is covered by Sheet 8 Taupo (Grindley 1960), Sheet 9 Gisborne (Kingma 1964) and Sheet 11 Dannevirke (Kingma 1962). However these maps record rocks on a time-stratigraphic basis rather than a lithological basis, and do not show cover deposits. They are also at a smaller scale than the NZLRI worksheets. For these reasons these maps were of limited value, and extensive field work was normally necessary. The location of geology and rock type maps used in the Northern Hawke's Bay Region are shown in Figure 6. For all bibliographic references refer to Appendix 8. A number of NZ Soil Bureau Reports and Bulletins provided information on the distribution of tephra within the Region. Principal among these are those of Healy *et al.* (1964) and Pullar and Birrell (1973).



CLIMATE TYPES

B2 Sheltered areas which recieve rains of high intensity at times from the northeast and north. Warm summer and cool winters with frequent ground frosts. Annual rainfall 1500 to 2500mm with a winter maximum.

C1 Very warm summers day temperatures occasionally rise above 30°C with dry foehn northwesteriies. Annual rainfall 1000 to 1500mm. marked decrease in amount and reliability of rain in spring and summer. Moderate winter temperatures with maximum rainfall in this season,

C2 Drier than C]. rainfall 600 to 1000mm. Summer droughts common.

C3 Cooler and wetter than C]. Very heavy rain at times from south and southeast. Annual rainfall mainly 1500 to 2500 mm.

M High rainfall mountain climates. Conditions very greatly with altitude and exposure.

○ Open stations

● Closed stations

Figure 4: Climatic regions of the Northern Hawke's Bay Region (New Zealand Meteorological Service 1983b), and location of climatological stations within and adjacent to the Region (New Zealand Meteorological Service 1983c).

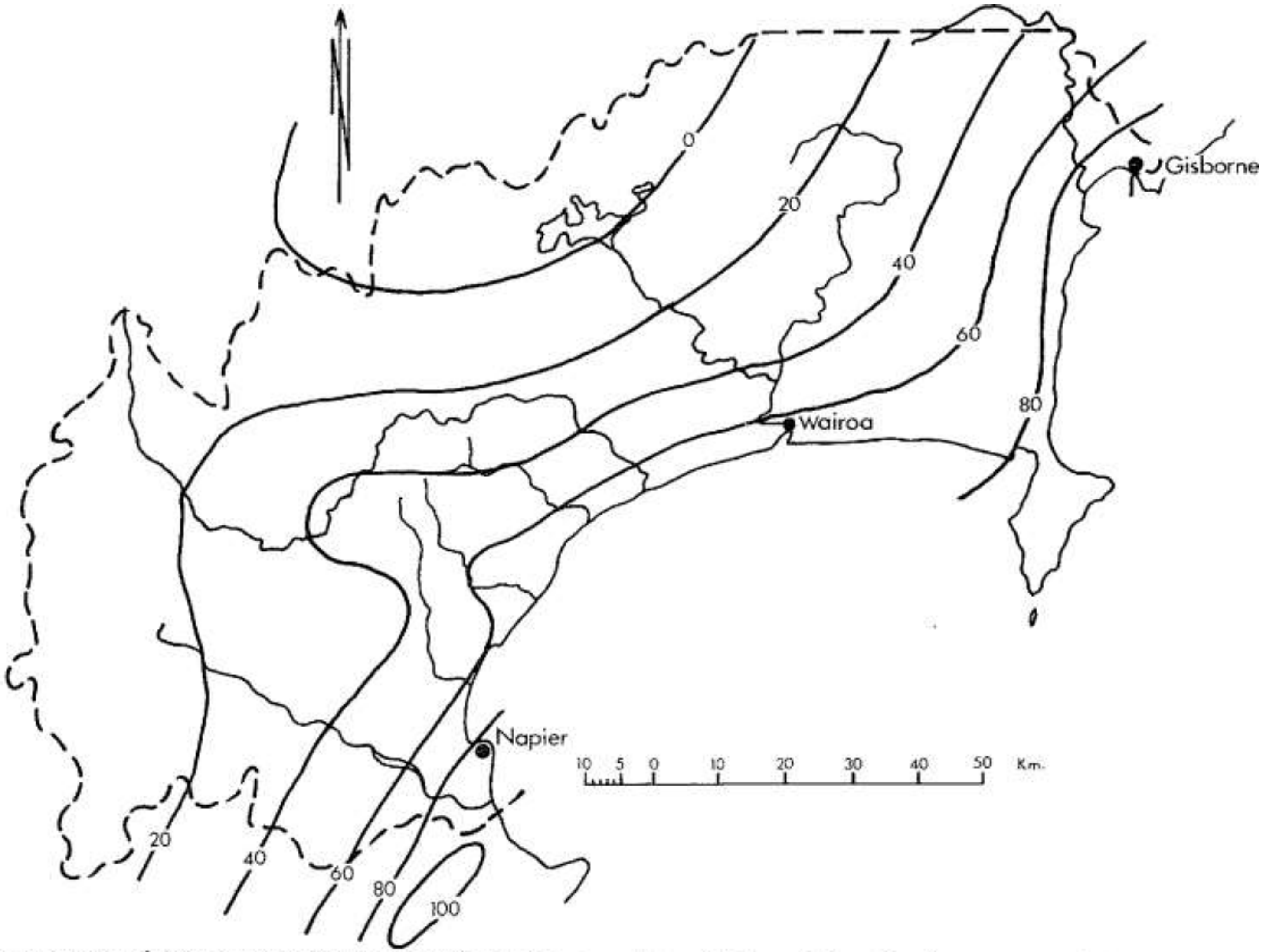


Figure 5: Average percentage of the growing season during which deficient monthly rainfalls result in soil moisture reserves being depleted by more than 8 cm (from de Lisle and Patterson 1971).

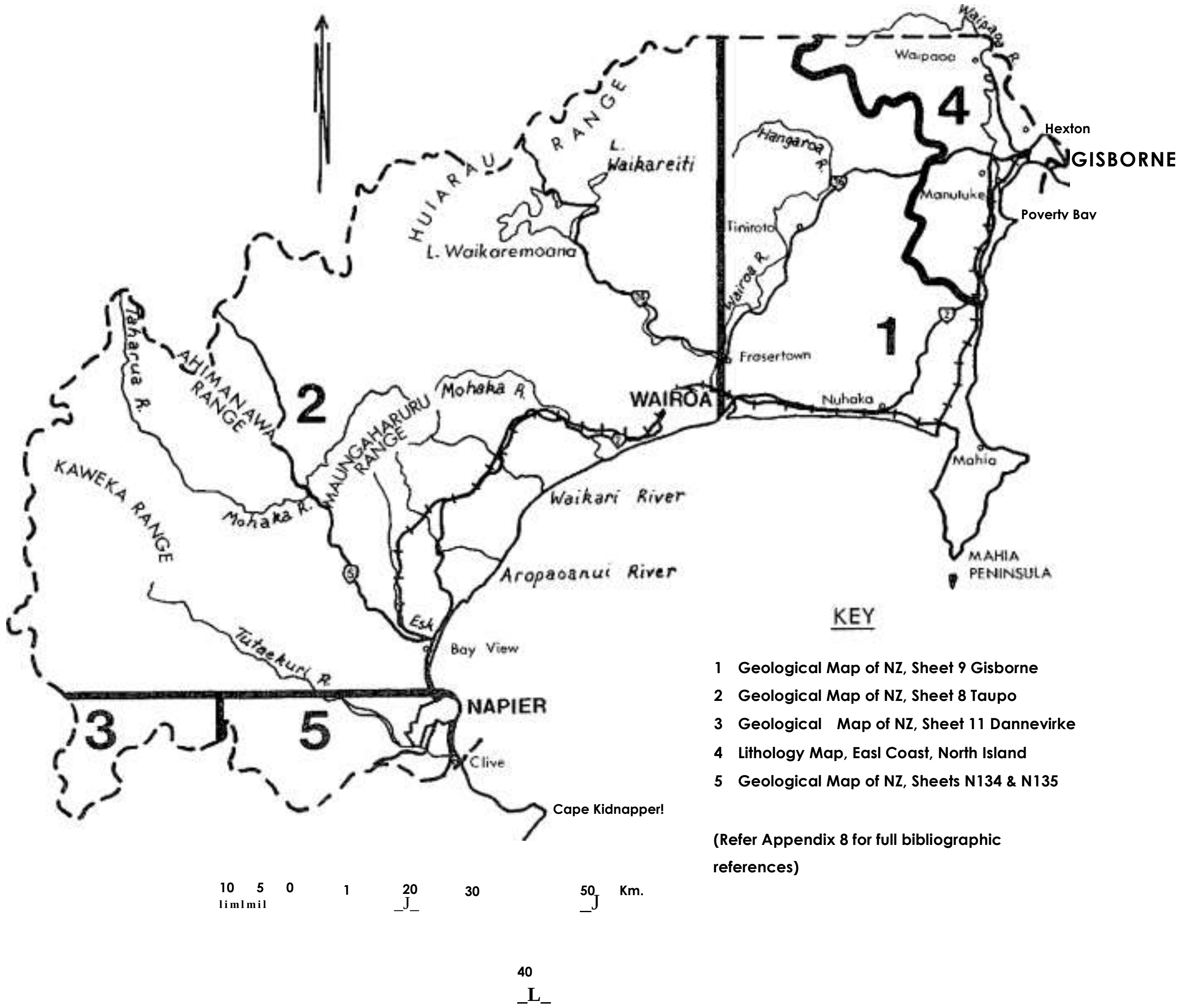


Figure 6: Location of geological surveys used in the Northern Hawke's Bay Region.

Table 2: NZLRI rock types exposed at surface in the Northern Hawke's Bay Region

Rock type*	Symbol	Area (ha)	% of Region
Ashes older than Taupo Pumice	Mo	301,630	26.2
Ashes older than Taupo Pumice —patchy cover	(Mo)	136,880	11.9
Massive sandstone or coarse siltstone	Sm	131,130	11.4
Massive mudstone or fine siltstone	Mm	97,950	8.5
Jointed mudstone or fine siltstone	Mj	83,480	7.2
Banded mudstone or fine siltstone	Mb	63,890	5.5
Banded sandstone or coarse siltstone	Sb	58,570	5.1
Taupo airfall tephra	Kt	57,170	5.0
Undifferentiated floodplain alluvium	Al	56,530	4.9
Greywacke	Gw	50,730	4.4
Taupo airfall tephra—patchy cover	(Kt)	25,450	2.2
Loess—patchy cover	(Lo)	24,350	2.1
Taupo flow tephra and volcanic alluvium	Tp	20,310	1.8
Loess	Lo	7,950	' 0.7
Windblown sands	Wb	4,570	0.4
Gravels	Gr	3,660	0.3
Lapilli	Lp	2,900	0.3
Limestone	Li	1,570	0.1
Lapilli—patchy cover	(Lp)	610	0.1
Peat	Pt	130	0.0
Ignimbrites (welded)	Vo	90	0.0
Lakes, rivers, urban areas etc		22,230	1.9

*Does not include secondary rock types

Table 3: NZLRI rock types influencing land use in the Northern Hawke's Bay Region

Rock type*	Main Rock		Mid Rock		Top Rock		Total	
symbol	area (ha)	% Region	area (ha)	% Region	area (ha)	% Region	area (ha)	% Region
Mo	9,920	0.8	63,520	5.5	434,240	37.7	507,680	44.0
Gw	281,660	24.4	—	—	—	—	281,660	24.4
Sm	271,690	23.5	—	—	260	0.0	271,950	23.6
Sb	147,170	12.7	—	—	530	0.0	147,700	12.8
Mj	126,020	10.9	—	—	1,520	0.1	127,540	11.0
Mm	115,110	9.9	—	—	—	—	115,110	9.9
Kt	30	0.0	—	—	82,600	7.1	82,630	7.1
Mb	68,040	5.9	—	—	690	0.0	68,730	5.9
Al	56,940	4.9	—	—	1,570	0.1	58,510	5.0
Lo	440	0.0	—	—	31,860	2.7	32,300	2.8
Lp	720	0.0	16,220	1.4	3,510	0.3	20,450	1.7
Tp	20,310	1.7	—	—	—	—	20,310	1.7
Gr	14,930	1.2	—	—	—	—	14,930	1.2
Li	5,540	0.4	—	—	—	—	5,540	0.4
Wb	4,570	0.3	—	—	—	—	4,570	0.3
Vo	3,050	0.2	—.	—	—	—	3,050	0.2
Me	2,230	0.1	—	—	—	—	2,230	0.1
Pt	130	0.0					130	0.0

*Does not include secondary rock types.

Rock types recorded in the Region are shown in Tables 2 and 3. Table 2 lists surface rock types, which are those that form the soil parent material. Table 3 lists all rock types recorded in the NZLRI inventory, i.e. rock types influencing land use, and consists of three categories: the top rock, which are those rock types that occur at the surface and overlie other rock types; midrock, which are rock types interbedded in a stratigraphic sequence; and main rock, which includes two situations, the underlying rock type recorded in a sequence and where only a single rock type is present, with no overlying rock types. For a schematic representation of these categories see Figure 7.

The following is a brief description of the rock types in the Northern Hawke's Bay Region. Nineteen different rock types were recorded in the NZLRI and these can be arranged into 4 groups: sedimentary rocks, volcanic rocks, volcanic cover deposits and non-volcanic cover deposits.

Sedimentary rocks

This is by far the largest group, containing 9 rock types. Sedimentary rocks occur practically throughout the Region, although in certain areas, particularly in the west and south, they are overlain by a variety of cover deposits. They range from Pleistocene to Triassic in age (1-230 million years old) with the oldest rocks occurring in the mountain ranges on the western margin of the Region. The rocks become progressively younger towards the east. The major sedimentary rocks are greywacke, massive and banded sandstone, and jointed, massive and banded mudstone or siltstone. They vary in hardness from very soft mudstones near the coast to the hard greywacke of the mountain ranges. In general the relief in the Region relates to both strength and hardness of the underlying rocks. Minor rock types include limestone, bentonitic mudstone and crushed argillite. The distribution and properties of limestone throughout most of the Region have been described by Moore and Hatton (1985). In the south-east of the Region conglomerate and limestone beds occur interbedded with sandstone and siltstone. On the NZLRI worksheets these conglomerates are mapped as gravels.

Greywacke forms the main mountain ranges while the main rock types in the hill country are mudstones, siltstones and sandstones. Within the hill country cuestas formed from banded sandstones and mudstones are common. Prominent ranges and ridges are usually capped with beds of limestone, conglomerate or sandstone.

Volcanic rocks

Volcanic rocks are limited to a small area of ignimbrites where the Region borders onto the central volcanic plateau in the vicinity of the Upper Rangitaiki Plains. They are welded rhyolitic rocks, erupted as pyroclastic flows, and form part of extensive sheets which give rise to characteristically subdued topography which has subsequently been mantled by tephras. These rocks are Pleistocene in age (0.5-1 million years old) and are part of two separate ignimbrite sheets, the Rangitaiki ignimbrites and the Te Whaiti ignimbrites.

Volcanic cover deposits

A number of tephras have been deposited within the Northern Hawke's Bay Region. They have originated from the Taupo, Okataina and Tongariro Volcanic Centres during Holocene and Pleistocene times, and consequently are thickest in the west of the Region. Although some tephras reached the coast subsequent erosion has meant that today the presence of tephra in the east of the Region is irregular, being absent on steeper slopes and generally only shallow on easier slopes. Tephras are valuable as marker beds in the interpretation of landscapes (Pullar 1967). The presence or absence of specific tephras provides an important tool for establishing the erosion history of the Northern Hawke's Bay Region.

These tephras had three modes of deposition (Rijkse 1974d). Airfall tephra comprises the largest part of the volcanic deposits in the Region. It was ejected into the atmosphere and carried by wind currents, with the finest material being carried furthest from source. The tephra on hill and mountain slopes has an airfall origin. Flow tephra is derived from nuees ardentes. These are incandescent clouds of gas and volcanic ash which flowed rapidly

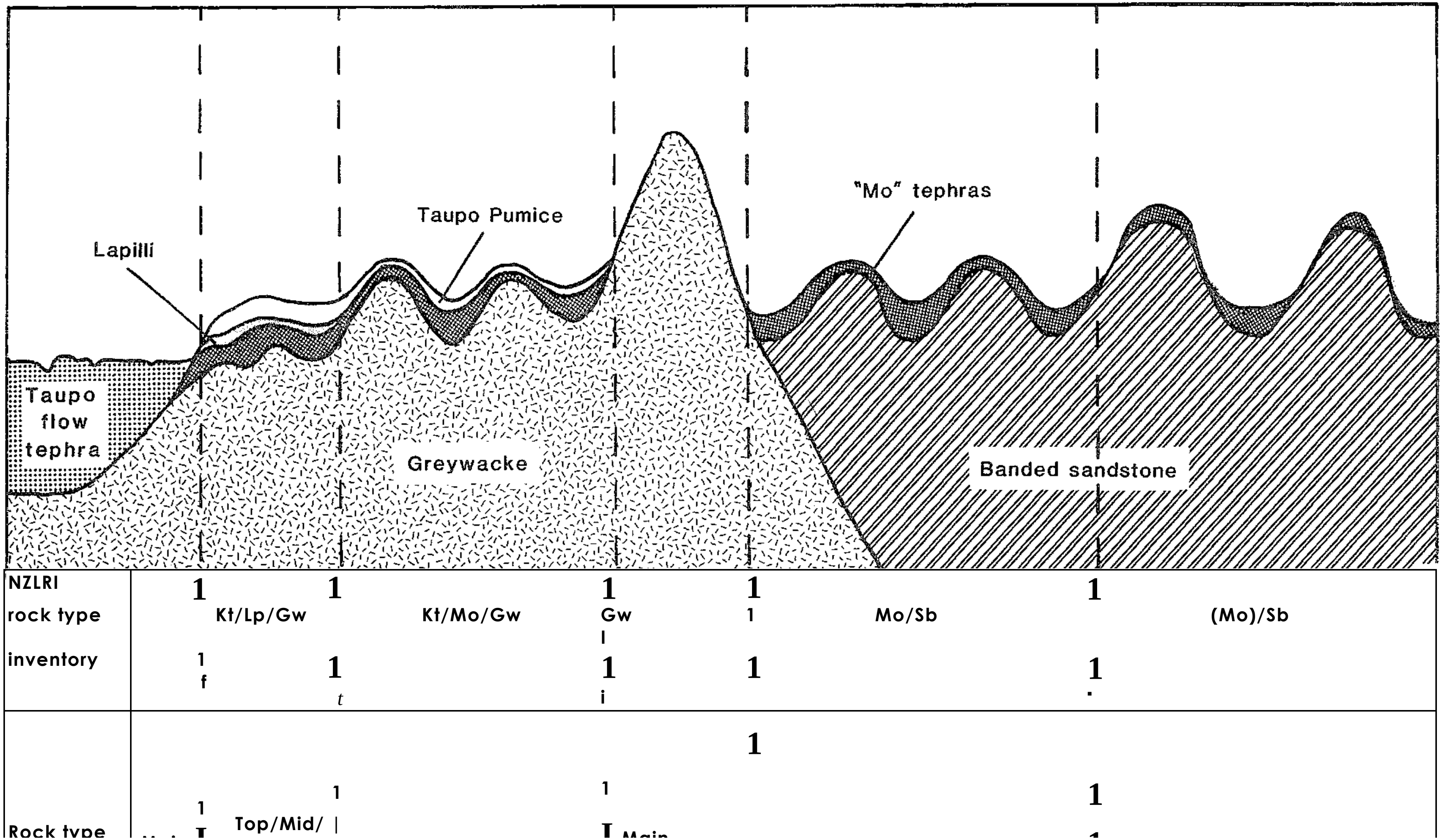


Figure 7: Schematic representation of the relationship between rock types in the Northern Hawke's Bay Region as recorded in the NZLRI (see Table 3).

Table 4: Summary of principal tephras in the Northern Hawke's Bay Region (largely based on Pullar *et al.* (1973)

Tephra bed or formation	Volcanic centre	Approx. age (yrs before 1950)	Mineralogical composition	Distribution	NZLRI symbol	Notes
Ngauruhoe Tephra	Tongariro	0-400	c	Ngamatea basin	Ng	Trace only
Kaharoa Ash	Okataina	900	Andesitic	Ureweras	Kt	5 cm near Lake Waikaremoana
Taupo Pumice	Taupo	1,800	Rhyolitic	Widespread	Kt	Thickest in north-west, thin to absent at coast, absent in south-east. Includes flow and water-sorted tephra (Tp)
Waimihia Formation	Taupo	3,400	Rhyolitic	Widespread	Lp	Up to 50 cm of lapilli at Mahia Peninsula and Raupunga
Rotoma Ash	Okataina	7,300		North of Region	Mo	Variable, 0-50 cm, difficult to differentiate
Waiohau Ash	Okataina	11,200		North of Region	Mo	
Tongariro Ash	Tongariro	2,500—20,000		South-west of Region	Mo	From >1 m in west, to trace on coast
Oruanui Ash	Taupo	19,800		Widespread	Mo	Significant only on stable sites
Rotoehu Ash	Okataina	41,700		Widespread	Mo	

Andesiti
c
Rhyoliti
c
Rhyoliti
c

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Rhyoliti
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Rhyoliti

overland (Froggatt 1981). This material is found only in the west of the Region and is confined to low points in the landscape, i.e. river valleys, plains. Water-sorted tephra is both airfall and flow tephra that has been eroded and redeposited by water, and as such is found as terraces in river valleys. Water-sorted tephra is generally finer than flow tephra and is further from source.

A list of principal tephras in the Region is given in Table 4. The principal features of these tephras and their stratigraphic relationships are provided in a comprehensive list of central North Island tephras given by Pullar *et al.* (1973). These tephras have been grouped into four rock types based on their erosion characteristics and responses to land use and management. (Not all of the tephras that occur within the Region are thick enough to be recorded as a rock type). Taupo ashes (Kt) are airfall tephras of the Taupo Pumice Formation and consist of fine to coarse ash and sometimes lapilli. It is mapped where its thickness is greater than 40 cm. In the extreme north-west of the Region shallow Kaharoa Ash is included in this rock type. Lapilli (Lp) is mapped where lapilli beds are greater than 60 cm thick. Although mainly consisting of Waimihia Lapilli, significant deposits of Taupo Lapilli are also included. Taupo flow tephra and volcanic alluvium (Tp) includes the flow tephra component of the Taupo Pumice Formation and water-sorted tephra. Ashes older than those of the Taupo Pumice Formation are grouped together (Mo). They are clay-rich and have weathered to the stage where they behave in a similar fashion in response to land use. They include Rotoma Ash, Waiohau Ash, Tongariro Ash, Oruanui Ash, Rotoehu Ash and deposits of tephric loess.

Non-volcanic cover deposits

This group contains the presently accumulating materials in the Region. There are five rock types: three are water deposited, alluvium, gravels and peat; and two are wind deposited, loess and windblown sand. Although largely derived from sedimentary rocks, two of these rock types, alluvium and loess, have significant tephric components. Alluvium and gravels form wide plains at Napier, Wairoa and Gisborne and narrow river terraces in the hill country, with peat limited to low and poorly drained sites. Alluvial plains along the coastline are bordered by a narrow strip of windblown sands which form a mosaic of sand dunes and sand plains.

The south-east of the Region has been mantled by loess. This is a very uniform material, unstratified and consisting predominantly of silt-sized particles. It is a slowly accumulating windblown deposit derived largely from sediment in nearby rivers. It is found on older higher terraces, downland and hills, although as with tephras, much has been eroded from the steeper slopes.

SOILS

The soil information on the worksheets is based on published or publicly available soil surveys provided by Soil Bureau, DSIR. A list of the surveys used in the Northern Hawke's Bay Region is given in Table 5, together with a 'short name' for each survey, which is used to refer to that survey in the rest of this bulletin. The locations of these surveys are shown in Figure 8. For full bibliographic references refer to Appendix 9.

In areas which only have soils coverage at scales smaller than that of the worksheets (1:63,360), especially those areas covered by the General Survey (NZ Soil Bureau 1954), more detailed soils information was required. 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 or soil series which were already recognised by Soil Bureau. In the case of the General Survey the relevant soil map 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 and Leamy 1980).

Table **5:** Soil surveys used in the Northern Hawke's Bay Region

Survey Number (Figure 8)	Survey Name	Author and Date	Scale	Short Name
1	General Survey of the soils of North Island, New Zealand	New Zealand Soil Bureau 1954	1:253,440	General Survey
2	Soils and some related agricultural aspects of Mid Hawke's Bay	Pohlen *et al. 19*	1:95,040	Mid Hawke's Bay Survey
3	Soils and agriculture of Gisborne Plains	Pullar 1962	1:15,840	Gisborne Plains Survey
4	Soils of Wairoa County*	Rijkse unpublished	1:63,360	Wairoa County Survey
5	Soil map of Taupo County	Rijkse in prep.	1:63,360	Taupo County Survey
6	Soils of Rangitikei County	Campbell 1979	1:63,360	Rangitikei County Survey
7	Land utilisation	Department of	1:23,760	Heretaunga Plains

* Since published as Rijkse 1979a, 1979b, 1980 at a scale of 1:100,000

It should be noted that 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, the boundaries 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 pedologist.

Typical soils recorded for each LUC unit are listed in the Northern Hawke's Bay Region Land Use Capability Extended Legend.

Soil Groups

Tephra or sedimentary rocks form the parent material of most of the soils in the Region. Other significant parent materials include loess and alluvium, both derived from sedimentary rocks and in most cases minor amounts of tephra.

There are six major soil groups (NZ genetic soil classification, NZ Soil Bureau 1968) which together cover over 90% of the Region. A list of all the soil groups in the Region together with area and percentage of Region is given in Table 6.

The following are brief notes on the six major groups:

Yellow-brown pumice soils and related steepland soils:

These soils comprise 28.2% of the Region. They are developed on the following rhyolitic tephras, Kah'aroa Ash, Taupo Pumice and Waimihia Formation. The combined depth of rhyolitic tephra exceeds 50 cm (may be less in the case of steepland soils). They are widespread throughout the centre of the Region much of which is hill country.

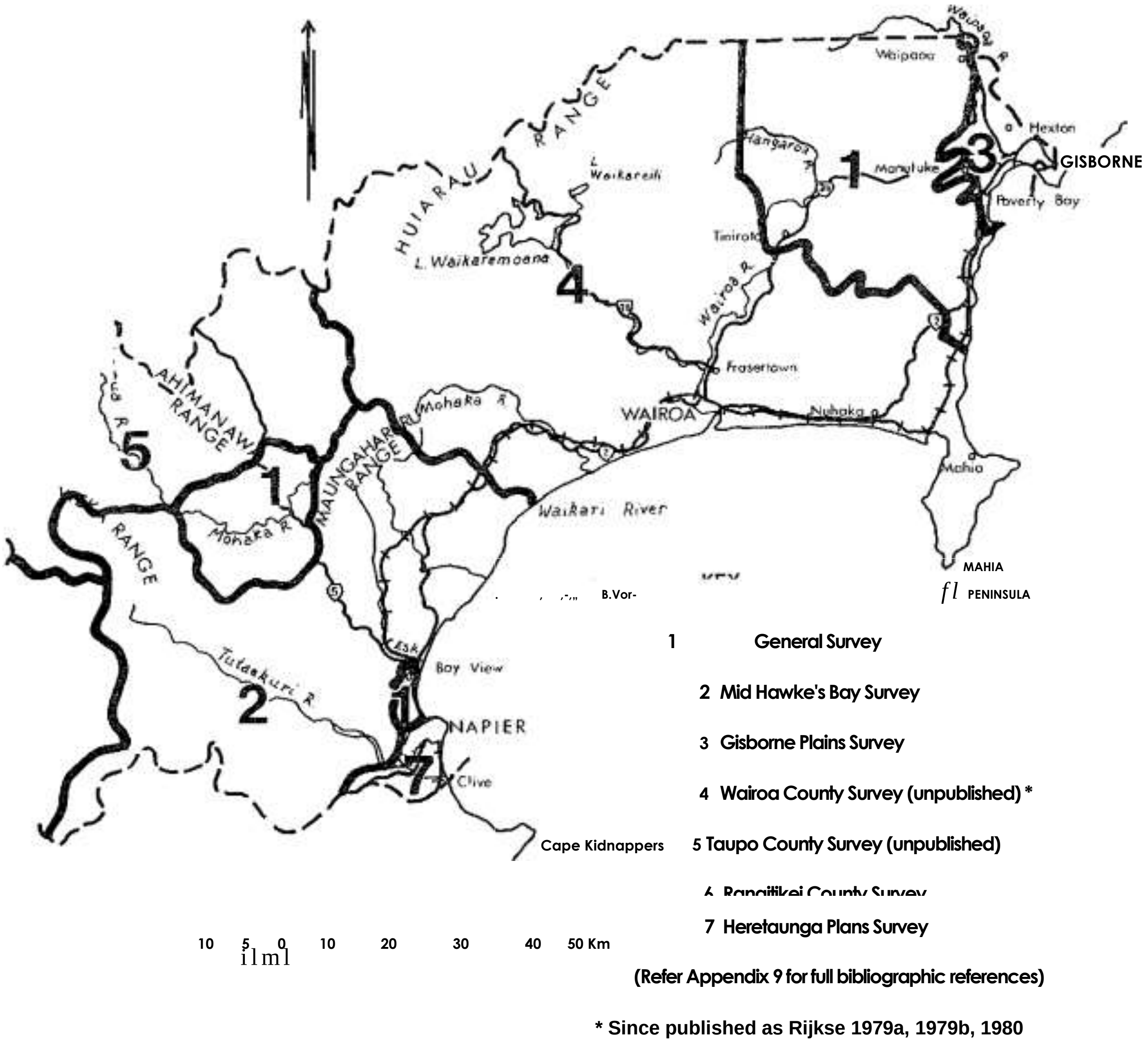


Figure 8: Location of soil surveys used in the Northern Hawke's Bay Region.

Table 6: Soil groups of the Northern Hawke's Bay Region

Soil group	Area (ha)	% of Region
Recent soils from alluvium	26,200	2.3
Gley recent soils	18,930	1.6
Saline gley recent soils	6,890	0.6
Organic soils	2,210	0.2

Podzolised yellow-brown pumice soils and related steepland soils:

These soils comprise 28.7% of the Region. Developed from the same rhyolitic tephras as yellow-brown pumice soils, they occur in the north-west, mainly in and around the main ranges. Depth of tephra is therefore usually greater than that of the yellow-brown pumice soils to the east. Here the altitude is greater than 500 m a.s.l. and the annual rainfall is in excess of 1500 mm. This has led to the leaching of nutrients and the formation of iron bands in the subsoil.

Yellow-brown earths and related steepland soils:

These soils comprise 13.7% of the Region. They occur mainly in hill country in the north-east. They are developed on sedimentary rocks, principally mudstones, siltstones and sand-stones, where annual rainfall is in excess of approximately 1200 mm.

Composite yellow-brown pumice soils on yellow-brown loams, and related steepland soils:

These soils comprise 9.6% of the Region. They occur in areas where Taupo Pumice and Waimihia Formation is less than 50 cm in depth and overlie older more weathered tephras. Thus the soils are described as composite, the upper part of the profile having the characteris-tics of a yellow-brown pumice soil and the lower part of the profile having the characteristics of a yellow-brown loam. These soils occur in two distinct areas of the Region; on flat to moderately steep slopes in central coastal areas, and in the south-west of the Region on a wide range of slopes associated with the main ranges.

Table 6: Soil groups of the Northern Hawke's Bay Region

Yellow-brown sands	4,020	0.3
Yellow-brown pumice soils	273,230	23.7
related steepland soils	51,490	4.5
Podzolised yellow-brown pumice soils	124,420	10.8
related steepland soils	205,750	17.9
Composite yellow-brown pumice soils on yellow-brown loams	31,870	2.8
related steepland soils	78,180	6.8
Yellow-brown loams	6,090	0.5
related steepland soils	7,610	0.7
Yellow-grey earths	46,010	4.0
related steepland soils	32,110	2.8
Intergrades between yellow-grey earths and yellow-brown earths	630	0.1
related steepland soils	18,780	1.6
Yellow-brown earths	18,670	1.6
related steepland soils	139,390	12.1
Intergrades between yellow-brown loams and yellow-brown earths	5,530	0.5
Composite yellow-brown pumice soils on yellow-grey earths	25,740	2.2
Bare rock	5,800	0.5
Lakes, rivers, towns	22,230	1.9
	1,151,780	100.0
Steepland soils	533,310	46.3

Yellow-grey earths and related steepland soils:

These soils comprise 6.8% of the Region. They occur in the south-east on a wide range of terrain, from terraces through to bluffs and gorges. They are developed on loess and sedimentary rocks, principally sandstones, siltstones and limestones, where annual rainfall is less than approximately 1200 mm, and distinct dry periods occur.

Recent and gleyed recent soils from alluvium:

These soils comprise 3.9% of the Region. They are developed on alluvium from sedimentary rocks, mixed with minor amounts of volcanic ash. They occur on floodplains and along narrow valleys. They are confined to the east of the Region, often in coastal situations, the main areas being the Gisborne, Wairoa and Heretaunga Plains. Recent and gleyed recent soils, although separate soil groups are closely related, and so are described together.

Further information about soils is given in the section on land use capability suites. General information about the properties of soils within the Region can be obtained from a number of sources, such as NZ Soil Bureau (1968), National Resources Survey (1971), 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 15 gives a list of all soil series and soil sets recorded in the NZLRI in the Region, and the soil survey or surveys in which they are mapped.

SLOPE

Slopes are recorded using slope groupings which are standard for land resource mapping (Soil Conservation and Rivers Control Council 1971). Slopes recorded are those areally dominant in each map unit. Details of the slope classification are given in Appendix 12.

Slopes are measured in the field with a hand held clinometer or estimated visually. For areas that have not been visited in the field, slope groups are estimated from aerial photographs.

An analysis of the dominant slope groups in the Region is given in Table 7, which also shows the proportion of the various slope groups in the North Island.

The table reflects the fact that the majority of the Northern Hawke's Bay Region (84.5%) is hill country and mountainland. It also shows that the Region has proportionately less flat to strongly rolling land (25.3%) than the rest of the North Island (42.9%), but more moderately steep to very steep land (72.8% compared with 54.9%).

Table 7: Areas of dominant slope groups recorded in the Northern Hawke's Bay Region

Dominant Slope Group		Area (ha)	% of Region	% of North Island
A	(0-3°)	93,410	8.1	14.8
B	(4-7°)	18,100	1.6	6.4
C	(8-15°)	44,650	3.9	8.9
D	(16-20°)	135,060	11.7	12.8
E	(21-25°)	354,670	30.8	24.5
F	(26-35°)	323,290	28.1	22.8
G	(>35°)	160,370	13.9	7.6
Unmapped: lakes,	rivers, towns	22,230	1.9	2.2
		1,151,780	100.0	100.0

EROSION

Erosion is a significant limitation to land use in much of the Northern Hawke's Bay Region. As part of the 'East Coast Deformed Belt' erosion rates are high, although there are not the large areas of deep-seated erosion which are common in the area north of Gisborne and to a lesser extent south of Napier.

Erosion is a naturally occurring process, the past activity of which is indicated by many of the landforms in the Region. For today's landscape to develop from such relatively recent sediments, erosion rates, at least during sometime in the past, must have been relatively high.

Despite this the removal of the natural vegetation and the development of the land for use by man (both European and Maori) has led to increased erosion. Among the first recorded observations of erosion are those of Guthrie-Smith (1953), who described erosion occurring on his sheep Station at Lake Tutira in the 1880s. He stated:

> "Eastern Tutira, indeed, after a violent "buster", appears to have been weeping mud. From the edges of all ancient slips the water-sodden fringes drip with clay; new red-raw wounds smear the green slopes, scalp-shaped patches detach themselves, slipping downwards in slush and turf. Sometimes a whole hillside will wrinkle and slide like snow melting off a roof, its huge corrugations smothering and smashing the wretched sheep, half or wholly burying them in every posture".

Descriptions of erosion may have changed, but the processes have not.

The causes of erosion are complex and include combinations of the following: geological structure, rock type, faults, and crush zones, earthquakes, soil properties, slope characteristics (angle, shape, aspect), vegetation cover, land use practices and climatic factors (e.g. rainfall intensity and duration, wind and frost).

A number of studies have been made of erosion in the Region. One of the earliest was "Soil Conservation Studies Applied to Farming in Hawke's Bay" by Campbell (1945a, 1945b, 1946, 1950). Others include Cumberland (1947), Pohlen *et al.* (1947), Grange and Gibbs (1947), Grant (1966a), O'Byrne 91967), Bishop (1968), Eyles (1971), Cunningham (1974), Speden (1978), Kamp (1982) and Douglas *et al.* (1986).

Soil Conservation works are carried out by the Hawke's Bay Catchment Board over most of the Region, except on and just south of the Gisborne Plains, which is under the jurisdiction of the East Cape Catchment Board. The Hawke's Bay Catchment Board operates the Tutira and Nuhaka catchment control schemes and the Mohaka and Mahia wind erosion schemes within the Region. The early history of these boards (prior to 1970) is described by McCaskill (1973).

Erosion information on the worksheets is based on the NZLRI erosion classification (Eyles 1985). A brief outline of the classification and severity rankings is given in Appendix 13. Erosion mapping was carried out both in the field and from aerial photograph interpretation. For each map unit erosion type and severity were assessed.

The types of erosion recorded in the Region are shown in Table 8 together with the total area of map units affected by each type of erosion. It should be noted that the methods used to record 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 8: Types of erosion occurring in the Northern Hawke's Bay Region

Erosion Type	Inventory Code	Area of map units affected (ha)	% Region
Soil slip	sSl	530,300	46.0
Sheet	Sh	330,920	28.7
Debris avalanche	daF	189,270	16.4
Gully	G	101,800	8.8
Wind	W	93,870	8.1
Earthflow	eF	74,640	6.4

Soil slip and sheet are by far the most common erosion types, usually occurring in combination. A number of other erosion types in Table 8 occur together to form patterns or associations of erosion types. These erosion associations are mapped at 1:250,000 in the "Erosion Map of New Zealand Series". This series also records present and potential erosion severity and types and is derived from the NZLRI. Sheets 8, 9 and 11 (Page and Steel 1982, Page 1976b and Noble and Fletcher 1984) cover the Northern Hawke's Bay Region. A description of the erosion associations found in this Region is given in Appendix 16.

Tables 9 and 10 show the severity of erosion occurring in the Northern Hawke's Bay Region. In Table 9 the severity totals are derived from the first recorded erosion type in a map unit i.e. if the erosion inventory for a map unit is 2eF 1G, then the area of the map unit is assigned to the moderate category in the table. In Table 10 the severity totals are derived from the severity of every recorded erosion type in a map unit i.e. if the erosion inventory for a map unit is 2eF 1G, then the area of the map unit is assigned to both the moderate and slight categories in the table. Therefore Table 9 records the most severe erosion in a map unit while Table 10 records all erosion severities in a map unit.

Compared with the North Island (Table 9) as a whole, the Northern Hawke's Bay Region has a much smaller area with negligible erosion and a larger area affected by erosion, especially of moderate severity. A broad comparison of present erosion between this Region and the rest of New Zealand is provided by Eyles (1983).

Table 9: Severity of erosion recorded in the Northern Hawke's Bay Region (from first recorded erosion type in map unit)

Erosion Severity	Area of map units affected (ha)	% Region	% North Island
Negligible	261,150	22.7	38.1
Slight	509,730	44.3	41.3
Moderate	282,090	24.5	13.9
Severe	60,310	5.2	2.9
Very severe	13,820	1.2	0.9
Extreme	2,450	0.2	0.7
Rivers, lakes, towns	22,230	1.9	2.2
	1,151,780	100.0	100.0

Table 10: Severity of erosion recorded in the Northern Hawke's Bay Region (from every recorded erosion type in map unit)

Erosion Severity	Area of map units affected (ha)	% Region
Negligible	261,150	22.7
Slight	931,370	80.7
Moderate	379,040	32.9
Severe	82,240	7.1
Very severe	19,500	1.6
Extreme	3,320	0.2

VEGETATION

Vegetation cover was assessed for each map unit, using a classification of 45 vegetation classes arranged into 5 major groups: grassland, cropland, scrubland, forest and miscellaneous associations (Appendix 14). Up to 3 vegetation classes were recorded in each map unit, with percentage cover being estimated as greater or less than 40% and with a minimum of 10%. Vegetation classes were also arranged in descending order of percentage cover. Information on vegetation cover was derived from fieldwork and aerial photograph analysis, supplemented by published maps and descriptions. A full description of the classification and method of recording are given in a vegetation cover classification bulletin (Hunter and Blaschke, 1986).

Vegetation maps in the Region are confined to areas of indigenous forest, most of which have been covered by Forest Service Mapping Series 6, at a scale of 1:250,000 (Sheets 6, 7, 10, 13), and by FSMS 5, at a scale of 1:63,360 (N95, 96, 104, 105, 114) (see Figure 9). For full bibliographic references refer to Appendix 10. In addition a number of descriptions of the vegetation of the main ranges are available, including: McKelvey (1973) for the Urewera

Ranges; Elder (1962) for the Kaimanawa Ranges; Elder (1959) and Cunningham (1974) for the Kaweka Range; Elder (1965) for the Ruahine Range; and Wallis (1966) for the Upper Ngaruroro Catchment.

The broad vegetation pattern of the Region has been described in the section on land use. At least 10 years has elapsed since this Region was mapped as part of the NZLRI. During this time some significant changes in vegetation have occurred, principally increases in exotic forestry and cropping at the expense of pasture, and the development of pasture from scrub. For these reasons no summary tables showing areas of vegetation are given. Rather, a brief description of the distribution of the vegetation classes is given in the following paragraphs. The classes will be discussed in the order in which they appear in the vegetation classification. (A glossary of plant names used in the text is given in Appendix 18).

Introduced pasture is the most extensive vegetation cover in the Region, dominating the hill country and to a lesser extent the coastal plains, and reaching inland as far as the foothills of the main ranges. It consists of two vegetation classes, high producing pasture (Pi) which occurs on the majority of flat and rolling land and easier hill country, and low producing or native grassland (P_2) which occurs on much of the steeper hill country, areas of low fertiity and in inacessible areas.

High producing pasture is dominated by ryegrass and white clover, but also includes such species as cocksfoot, prairie grass, timothy, crested dogstail, red clover and subterranean clover.

The main low producing pasture species are browntop, danthonia, Yorkshire fog, sweet vernal and ratstail. Flatweeds and mosses may also be conspicuous. Major weeds include thistles, (especially nodding, Californian, winged and variegated thistle), barley grass and ragwort. Rushes are common in both high and low producing pasture on poorly drained sites.

Three tussock grassland classes occur in the Region, all in the higher altitude areas of the Kaimanawa, Kaweka and Northern Ruahine Ranges.

Short tussock associations (P_3) occur at lower levels or where forest destruction has occurred. Four main tussock species characterise this class in the Northern Hawke's Bay Region. Bristle tussock and to a lesser extent blue tussock are found in association with scrub on the steep, eroding slopes within the Upper Ngaruroro and Taruarau catchments and on the Kaweka Range. Hard tussock and silver tussock are common on the pumice terraces of the Taharua, Waipunga and Ripia Rivers.

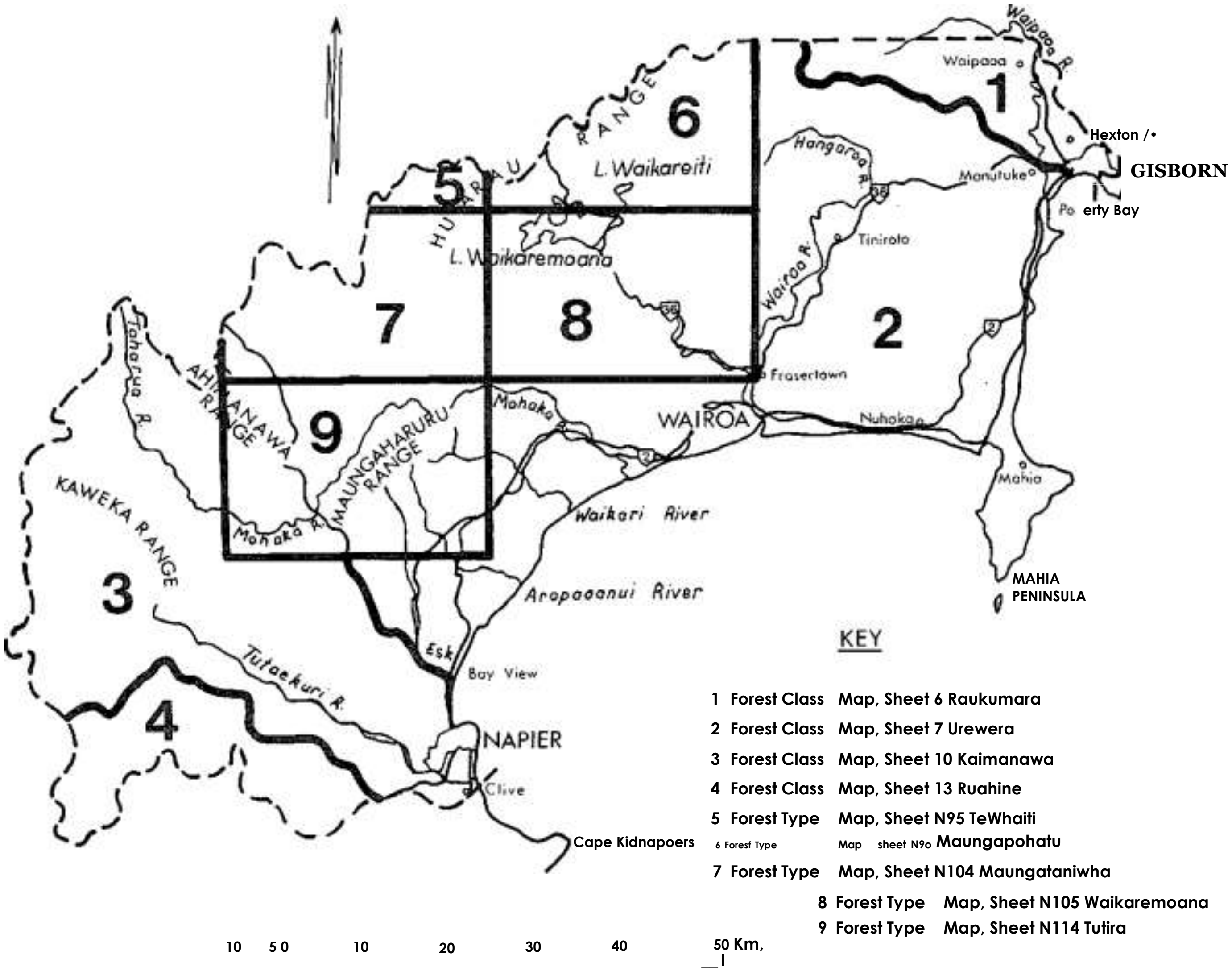
Snow tussock associations (P_4) occur at the highest elevations, generally above the tree line but locally descending to about 1,300 m a.s.l., and are dominated by mid-ribbed snow tussock. This class occurs on the crest of the Kaweka Range, the Northern Ruahine Range and on a number of high points near the divide between the Ngaruroro and Rangitikei Rivers.

Between approximately 1000-1300 m a.s.l. red tussock associations (P_5) are dominant, often occurring on poorly drained sites. This tussock covers the pumice terraces in the Upper Ngaruroro and Taruarau catchments, in association with monoao, and also undulating high plateaux such as Mt Meany, The Comet and Ruahine Corner.

The main areas where crops are grown are on the three major alluvial plains at Gisborne, Wairoa and Napier. Other significant areas include the Nuhaka, Mohaka and Esk Valleys and on Mahia Peninsula.

The major cereal (LJ grown in the Region is maize, both as a cash and feed crop. It is particularly common on the Gisborne and Wairoa Plains. Only minor amounts of barley, oats and wheat are grown.

Orchards and vineyards (L_2) are found mainly on the Gisborne and Heretaunga Plains. Tree fruit types include apples, pears, apricots, cherries, nectarines, peaches, plums and citrus. Vineyards include both grapes and kiwifruit. Other subtropical fruit such as feijoas, passionfruit and avocados, although limited in extent, are included in this class. With a recent increase in the area of orchards and vineyards they are now spreading beyond the main plains into nearby valleys.



(Refer Appendix 10 for full bibliographic references)

Figure **9:** Location of vegetation maps used in the Northern Hawke's Bay Region.

Root and green fodder crops (L_3) are grown throughout the Region in alluvial valleys and on undulating to strongly rolling downland. Crops include chou moellier, turnips, swedes, rape, pumpkins and maize.

The area of horticultural crops (L_4) is much less than the other three classes, but within this area a wide range of these crops are grown. The main vegetable crops are sweet corn, peas, beans, tomatoes, potatoes, asparagus, kumara, onions, lettuce, cabbage, cauliflower, carrots, celery, capsicums and pumpkins. This class also includes berryfruit: mainly strawberries, boysenberries and raspberries.

Although the area of scrub has been reduced over the years as land has been developed and redeveloped into pasture, there still remain significant areas of scrub, both as large blocks and scattered throughout pasture. By far the most common scrub is manuka (M^. This class also includes kanuka which in this Region is more limited in extent. Manuka is common on, but not confined to, steep, less fertile or inaccessible areas, particularly in high rainfall areas bordering the main ranges. Manuka is also characteristic of a large area within the main ranges centred on the Napier-Taihape Road. Here it has developed as a result of burning of the original vegetation, and grows in association with tussock and sub-alpine scrub to an altitude of 1300 m a.s.l. In the hill country this class typically consists almost entirely of manuka with few other species present, especially in the canopy. However manuka is one stage in the sequence of reversion back to forest. With time an increasing number of broad-leaved species appear in the canopy and eventually supress the manuka, at which stage it is mapped as mixed native scrub associations.

On coastal cliffs and nearby hills tauhinu (M_2) replaces manuka as the predominant scrub, although it usually grows scattered within pasture or on cliff faces and rarely forms a complete canopy. Tauhinu extends further inland on the Wharerata hills between Gisborne and Nuhaka, although these hills may still be exposed to a coastal influence. It also occurs locally further inland but never in sufficient quantity to be recorded.

Monoao, a species of *Dracophyllum* (M_3) is found in a number of montane valleys, where it grows in association with red tussock or silver tussock on pumice terraces and surrounding low hills. This is an extension of the 'frost flat' vegetation characteristic of the Upper Rangitaiki Plains and occurs in the headwaters of the Taruarau, Ngaruroro, Taharua, Ripia and Waipunga Rivers. Another species of *Dracophyllum* occurs at higher altitudes as a minor component of sub-alpine scrub and so has been included within that class.

Fern (M_4) typically occurs on reverting farmland in areas of higher rainfall and as such is commonly associated with manuka and low producing pasture. The main areas of distribution are the margins of the Ureweras, the area from Whakapunake to the Wharerata hills, the flanks of the Maungaharuru Range, the middle reaches of the Mohaka River and the reverting hill country surrounding Te Haroto. The major fern species are ring fern and bracken.

Within the main ranges sub-alpine scrub (M_5) occurs above the treeline. In the Ureweras it caps a number of high points such as Maungapohatu, while in the Kaimanawa, Kaweka and Northern Ruahine Ranges it may grade into snow tussock at higher altitudes. In general the altitudinal range is 1250-1550 m a.s.l. Plants are usually less than 1 m high and consist of a large number of species. The major genera include *Olearia, Senecio, Coprosma, Hebe, Gaultheria, Cassinia, Dracophyllum* and *Dacrydium.*

Mixed native scrub associations (M_6) (except in specialised habitats) are a stage in the reversion cycle through to forest. This class occurs throughout the hill country within the Region and is often associated with manuka, although much less prevalent. Important constituents include *Coprosma, Hebe, Pittosporum,* mahoe, tutu, wineberry, five-finger, lancewood, rewarewa and tree ferns.

Two exotic scrub classes have been mapped in the Region. They are far less common than indigenous scrub and are restricted in their distribution. Gorse (M_8) has been recorded between Kotemaori and Nuhaka, and on Mahia Peninsula. This is an area relatively near the coast with an annual rainfall of less than 1500 mm. Gorse occurs scattered or in small clumps in hill country pasture.

Blackberry (M_9) has been recorded in a similar area to gorse, although it extends somewhat further inland. Like gorse it occurs in pasture where it forms clumps or 'thickets'. Both gorse and blackberry are more extensive in their distribution than is shown on the worksheets. This is because at the scale of mapping they seldom occupy sufficient area to be recorded. Blackberry particularly is present at low density over much of the Wairoa area.

Although much of the Region was originally covered in indigenous forest, today the only large tracts of forest are confined to the main ranges while numerous small remnants are scattered throughout the hill country. On the plains and downlands indigenous forest is almost entirely absent.

Although some coastal species may be present in a number of forest remnants, only on Mahia Peninsula has coastal forest (NO been recorded. Here ngaio, karaka and nikau are characteristic.

The majority of the hill country was once covered in lowland podocarp-hardwood forest (N_3a). Today several large stands remain, some of which have received reserve status. Small remnants are common on farmland, many of which are too small to be recorded. Nearly all of this remaining podocarp-hardwood forest has been cutover, although this has not been recorded in the inventory. Some areas of unlogged podocarp-hardwood forest still remain within the main ranges particularly in the Ureweras. The class occurs up to the altitudinal limit of rimu (approx. 850 m), which is one of the characteristic podocarps of the class. Others include totara, miro, matai and kahikatea. These trees emerge when mature from a canopy of hardwoods which in this Region is normally dominated by tawa. Other hardwoods include hinau, rewarewa, maire, pukatea and rata.

Mid-altitude podocarp-hardwood forest (N_3b) occurs above the altitudinal limit of rimu where podocarps such as Hall's totara, pink pine and mountain toatoa form a stunted canopy with kamahi and broadleaf. Throughout most of the Region, forest at this altitude is beech forest. Mid-altitude podocarp-hardwood forest occurs only along ridges bordering the Waipunga Valley, along the crest of the Ahimanawa Range and in the Northern Ruahine Range at No Man's Bog and near Ruahine Corner where kaikawaka is the podocarp species.

Beech forest is the most common forest in the main ranges and also occurs in several other places such as Whakapunake and the Maungaharuru Range. It has been subdivided into two vegetation classes on the basis of a combination of altitude and species. Lowland beech *(Nothofagus)* forest (N_4a) occurs up to an altitude of approximately 1050 m and consists mainly of red beech, with some hard and black beech'at lower altitudes and some silver beech at higher altitudes.

Highland beech forest (N_4b) occurs above approximately 1050 m a.s.l. and consists of mountain beech and silver beech. It also occurs below this altitude in some localities where because of site conditions mountain beech or silver beech are found. Towards the treeline highland beech forest becomes stunted and often wind-shorn. Both beech classes contain relatively low numbers of other species when compared with the diversity of podocarp-hardwood forests. However at lower altitudes in some areas a mixture of podocarp-hardwood-beech forests occur, where occasional podocarps and more abundant hardwoods are found in association with beech. These areas have been mapped as N_4a N_3a.

Hardwood forest (N_5) is mapped where podocarps and beeches are absent or nearly so, and the canopy is dominated by hardwoods. The main species is tawa, but kamahi, rewarewa and rata are also significant. This class has been mapped in two situations. Either where podocarp-hardwood forest has been logged to remove the significant podocarps, or where second growth forest has developed but where podocarps have not yet become significant. Areas which have been only lightly logged have still been mapped as N3a. In Regions mapped subsequent to the Northern Hawke's Bay Region, forests which have been cutover are identified by the prefix 'c'. Most N_5 was mapped on the margins of the Ureweras and the Ahimanawa Range.

Exotic forest (N_6) has been planted in many different areas throughout the Region, from sea level to 900 m, from flat terraces to very steep hill and mountain slopes, and on a wide variety of parent materials. The class includes all exotic tree species grown for wood production. Of these *Pinus radiata* is by far the most common species with other conifers such as Corsican pine, Douglas fir and larch making up most of the remainder. Hardwoods such as eucalypts are of very limited extent. Although the class typically occurs as large state or private forests, increasingly it also occurs as farm plantations or woodlots. Because of the 1:63,360 map scale many of the latter were not recorded.

Conservation trees (N_8) was only added as a vegetation class in 1976 and consequently only appears on worksheets compiled after that date. In this Region conservation trees were only mapped in the vicinity of the Kaweka Range where revegetation trials have been carried out using lodgepole pine and other species. Elsewhere conservation trees were either not mapped (usually poplars and willows) or mapped as exotic forest (usually *P. radiata).*

Swamp associations (H_x) have been mapped on the margins of lagoons along the coastline east of Wairoa. Other areas of sufficient size to be recorded are at the head of the Taharua River, the Ngamatea Swamp on the Napier-Taihape Road, and the Everglades, which is an area of silted lake beds in the Urewera National Park.

Areas of pasture with impeded drainage are commonly infested with rushes or sedges (H_2). Such areas are alluvial terraces or plains with inadequate drainage, colluvial footslopes within hill country, and hills formed from fine sediments. Rushes and sedges are also more common in areas of higher rainfall in the north of the Region.

Sand dune associations (H_3), comprising a range of woody and herbaceous species, are found along the coastline on sand and gravel deposits. They are usually dominated by lupins but in some areas may be entirely herbaceous. Sand grasses such as marram and spinifex may also be present. The major areas are in the vicinity of Napier, east of Wairoa and near Gisborne.

Sub-alpine herb associations (H_4) are found only on the highest points in the Region, in association with snow tussock. Such areas are the crests of the Kaweka Range and the Otupae Range.

The old Ahuriri Lagoon, an area just north of Napier which was uplifted in the 1931 earthquake, is still affected by salt water and here salt tolerant associations (H_5) have been mapped.

LAND USE CAPABILITY CLASSIFICATION

The land use capability (LUC) classification is an assessment of land in terms of its capacity for sustained productive use, taking into account physical limitations, management requirements and soil conservation needs. The assessment is based on an interpretation of the physical 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 is an assessment of the versatility of land and gives the general degree of limitation to use, taking into account the physical limitations to sustained production. 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, 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 grazing or production forestry, and is best managed for catchment protection (which may include some recreational uses).

All eight LUC classes have been mapped in the Northern Hawke's Bay Region. The area of each class, both in hectares and as a percentage, is given in Table 11. The most versatile and poten tially productive land, classes I and II, comprise only 2.2% of the Region, while land classified as classes VI, VII and VIII comprise 85.7% of the Region. The importance of the most productive land is therefore further increased by its scarcity.

Table 11: Areas of LUC classes mapped in the Northern Hawke's Bay Region

LUC Class	Area (ha)	% of Region	
I	11,110	1.0	
II	14,170	1.2	Arable
III	56,320	4.9	12.1%
IV	57,000	5.0	
V	3,800	0.3 '	Non-arable
VI	474,890	41.2	' 70.8%
VII	337,530	29.3	
VIII	174,730	15.2	Protection
			15.2%
Unmapped (rivers, lakes, urban areas etc.)	22,230	1.9	
TOTAL	1,151,780	100	

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. Four kinds of limitation are recognised: erodibility (e), soil limitations within the rooting zone (s), wetness (w) and climate (c). The initial letter of each limitation is used to identify the subclass (e.g., He, IIw, lis, lie). Only the dominant limitation is identified in the land use capability code. One or more other limitations may also exist but are described in the LUC extended legend.

The area of each of the four subclass limitations in the Northern Hawke's Bay Region, both in hectares and as a percentage, is given in Table 12. More detailed data are given in Appendix 1. Because of the large proportion of hill country and mountainland in the Region erodibility is by far the major limitation. Advances in understanding of the land since the time of the survey have led to the identification of all or part of five LUC units which would be better reclassified from e to s or c (see LUC suites 10, 11 and 16). As a result the percentages for the four subclass limitations would be as follows: climate 4.7%, erodibility 78.3%, soil limitations 11.4%, wetness 3.7%.

Table **12:** Areas of LUC subclass limitations mapped in the Northern Hawke's Bay Region

LUC Subclass Limitations	Area (ha)	% of Region
Climate (c)	16,480	1.4
Erodibility (e)	1,036,740	90.0
Soil Limitation (s)	33,880	3.0
Wetness (w)	42,450	3.7
Unmapped (rivers, lakes, urban areas etc)	22,230	1.9
TOTAL	1,151,780	100

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 which are identified by arabic numerals at the end of the LUC code. Each LUC unit groups together land inventory units which require the same kind of management, the same kind and intensity of conservation treatment and are suitable for the same kind of crops, pasture or forestry species with similar potential yields. LUC units within subclasses are arranged in order of decreasing versatility to use and increasing degree of limitation to use, e.g. VIIe5 has a higher use capability than VIIe8, but not as high as VIIe2.

The relationship between the three components of the classification is illustrated in Figure 10.

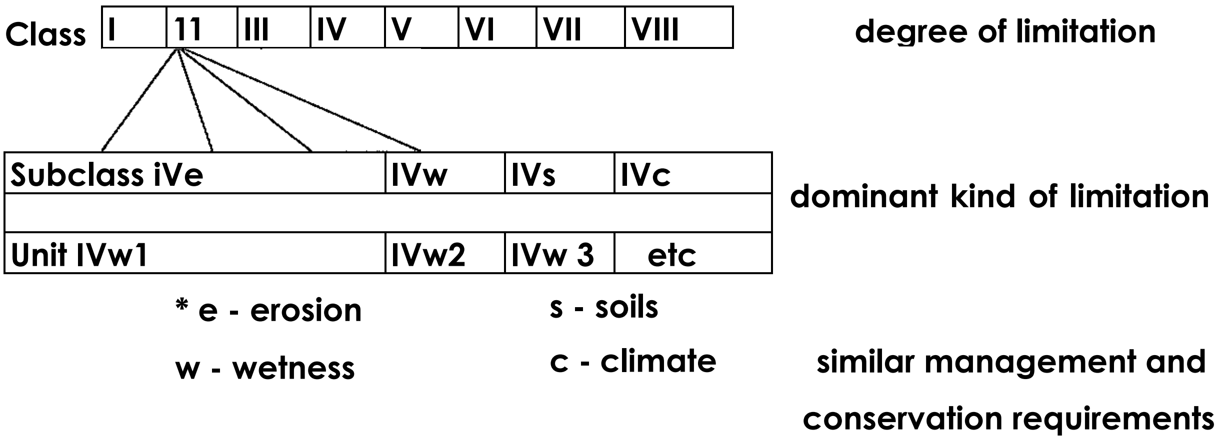


Figure **10:** Components of LUC classification.

A total of 81 LUC units have been identified in the Northern Hawke's Bay Region (Page 1976a). Appendix 1 lists the LUC units in capability order, and gives their areas in hectares and as a percentage of the Region. A correlation of Northern Hawke's Bay LUC units with those in adjacent regions is given in Appendix 2 (Page 1985).

For a detailed description of the Land Use Capability classification refer to the "Land Use Capability Survey Handbook" (Soil Conservation and Rivers Control Council 1971).

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. A LUC suite is defined as, "a group of LUC units which, although differing in capability, share a definitive physical characteristic which unites them in the landscape".

These 'definitive physical characteristics' may vary from suite to suite. The use of LUC suites as a tool in landscape assessment is discussed by Blaschke (1985a). In this Region rock type is the common basis for the definition of suites. Rock type has an important influence on landforms, slopes, soils, erosion forms, soil conservation measures, land management, productivity and hence on land use capability. The 81 LUC units have been arranged into 16 suites and these suites are described in detail in the next section. The LUC classifications for the Southern Hawke's Bay-Wairarapa Region (Noble 1985), Bay of Plenty-Volcanic Plateau Region (Blaschke 1985b) and Taranaki-Manawatu Region (Fletcher 1987) have also been described using the suite concept.

Productivity Data

Part of the definition of a LUC unit is that it groups areas of land with a similar potential (see p.35). Therefore with the completion of the inventory and LUC mapping aspect of the NZLRI a logical extension was to obtain production estimates for each LUC unit. These take the form of stock carrying capacity for pastoral production and site index for forestry production. This information was collected on a regional basis in co-operative exercises with the Ministry of Agriculture and Fisheries and the New Zealand Forest Service. Although not shown on the NZLRI worksheets this information is shown on several of the more recent regional extended legends and is stored as part of the computer data base. The extended legend for the Northern Hawke's Bay Region does not contain stock and forestry data.

These production estimates provide a quantitative link between land use capability and agriculture and forestry. They take the NZLRI beyond the physical description, or composition, of land and provide a measure of land performance.

Stock carrying capacities

Data on stock carrying capacity were collected in 1980 from farm advisory staff at Gisborne, Wairoa and Napier. Three levels of stock carrying capacity were assessed (expressed in terms of stock units per hectare): present average, top farmer and attainable physical potential. In addition, an assessment of fertiliser and trace element requirements for establishment and maintenance of pasture was also made. These assessments were made by field inspection of a number of representative sites of each LUC unit. Assessments of individual LUC units were also obtained from more than one Farm Advisory Officer where possible. From these assessments a single figure was agreed upon at a meeting between the NZLRI regional supervisor, the local Farm Advisory Officers and the Regional Advisory Officer. Rankings for stock carrying capacity figures are given in Table 13. The stock carrying capacity data for each LUC unit are given in Appendix 4.

Table 13: Stock carrying capacity rankings

Stock Carrying Capacity Ranking	Stock Units per Hectare
Very High	> 25
High	21-25
Moderately High	16-20
Medium	11-15
Low	6-10
Very Low	1-5
Sparse	< 1

Forestry site indices

Site index data were collected in 1981 from Foresters at Napier and Gisborne. Site index was chosen as the most suitable measure of forest growth and was defined as 'the mean top height or predominant mean height in metres of *Pinus radiata* at age 20 years'.

Again a number of representative sites of each LUC unit were visited and assessments of site index were made, based either on plot record information where forests were present, or on field observations of shelterbelts, woodlots, etc. A meeting was then held between the NZLRI regional supervisor and the Foresters in the Region to arrive at a consensus figure for each LUC unit.

Because of the site variation within LUC units, especially in hill country, site index data was recorded as a range rather than a single figure. In general most LUC units have site indices with a range of 2-5 metres. Rankings for site index figures are given in Table 14. The site index data for each LUC unit are given in Appendix 5.

Table 14: Site index rankings

Site Index Ranking	Site Index in Metres
Very High	> 35
High	30- -35
Medium	25- -29
Low	20- -24
Very Low	< 20

Previous Land Use Capability Surveys in the Region

Prior to 1973 LUC surveys were carried out on an ad hoc basis as a result of special requests, and usually on a catchment basis. In the Northern Hawke's Bay Region a number of such surveys were carried out at scales varying between 1:15,840 and 1:126,720 by soil conservators first in the Department of Agriculture and subsequently in the Ministry of Works. Table 15 lists these LUC surveys together with scale and date.

Staff of both the East Cape and Hawke's Bay Catchment Boards have prepared many LUC assessments for farm plans and catchment control schemes.

Table 15: Land use capability surveys in the Northern Hawke's Bay Region

Title	Scale	Author	Date
Kopuawhara Catchment	1:63,360	Kelman	1955
Gisborne/East Coast Region	1:126,720	Harris *et al.*	1964
Portion of the Ngaruroro River Catchment	1:31,680	Smith *et al.*	1965
Waiatai, Whakaki and Hereheretau River Catchments	1:15,840	Smith	1965
Poronui Station	1:15,840	Eyles	1969a
Waipunga Catchment	1:63,360	Eyles	1969b
Upper Ngaruroro Catchment	1:63,360	Eyles	1969c
Esk and Waikoau River Catchments	1:31,680	Stephens	1970

Other Land Classification Studies

Within the Northern Hawke's Bay Region several other land classification studies have been carried out. Two that have adopted a multifactor assessment of land for their particular purposes are the Wairoa District Land Resource Study (Black and Cairns 1983) and Ecological Regions and Districts of New Zealand (Simpson 1982).

The Wairoa District Land Resource Study was carried out by the Hawke's Bay Catchment Board. As part of this study a number of landform suites have been identified. These are defined as 'readily identifiable land units based on similarity of landform and erosion type. Each unit represents blocks of land that have undergone the same stages of landform development, exhibit the same erosion types and display a similar erosion potential'. Each landform suite is identified by a local name.

Each landform suite contains a number of LUC units. There is an approximate correlation between landform suites and LUC suites (see Appendix 3). Usually most of the LUC units in a LUC suite correlate to a particular landform suite. Sometimes part of several LUC suites are found in a landform suite.

Ecological Regions and Districts have been mapped throughout New Zealand at a scale of 1:500,000 on the basis of differences in geology, landform, climate, soil and flora and the extent of remaining indigenous vegetation. An Ecological District is defined as a geographic area with a reasonably distinct pattern of characteristic natural ecosystems. An Ecological Region is recognised where several closely related districts form an integrated unit. A single district can also be a region if it is highly distinctive or contains a wide but continuous range or repeating pattern of variation.

Part or all of a number of Ecological Regions and Districts occur within the Northern Hawke's Bay Region (see Appendix 17). Although not having any direct relationship to LUC suites there are nevertheless some similarities between the Ecological Regions and Districts and the distribution of LUC suites.

LAND USE CAPABILITY SUITES

Sixteen LUC suites (Table 16) have been differentiated in the Northern Hawke's Bay Region. The primary factor used to delineate these LUC suites is rock type, although other factors such as climate, erosion type and soils may also be characteristic. Within each suite variations in factors such as slope angle, erosion potential, wetness and stoniness are used to delineate LUC units.

Of the 16 LUC suites, 5 are defined by sedimentary rock types (LUC suites 5, 6, 7, 8, 9). Six are defined by volcanic cover deposits (LUC suites 11, 12, 13, 14, 15, 16), while 5 are defined by non-volcanic cover deposits (LUC suites 1, 2, 3, 4, 10).

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 few LUC units which do not fit well into a LUC suite. Also there are several LUC units which are described in two LUC suites. That is, areas classified as a particular LUC unit have been divided into 2 component areas, each of which is described in a different LUC suite.

Table 16: LUC suites and component LUC units in the Northern Hawke's Bay Region

LUC suite number	LUC suite name	Component LUC units
	Alluvial plains and terraces	IIIs3, IIIe3, IVe2, VIel, VIe6
	Gravel terraces	IVcl, VIell, VIc3, VIIel4, VIIIe2, VIIIe5, VIIIe6, VIIIe7
	Low lying saline plains	
	Sand dunes	IIIe2, IVe2, VIel
	Low angle, unstable mudstone terrain	
	Jointed mudstone hill country	
	Banded mudstone hill country	IVe3, VIel5, VIIel9
	Siltstone hill country	
	Sandstone hill country	IVs2, IVe5, VIIel6, VIIIe4
	a) calcareous	
	b) non-calcareous	VIel2, VIIe7, VllelS, VIIIe5, VIIIe6
10	Landforms with a mantle of loess	IVe4, IVw2, VIc2, VIel6, VIIel2, VIIel7, VIIel8, VIIIe8, VIIIe9, VHIelO, VHIell
11	Landforms with a mantle of Taupo airfall tephra a) lowland b) upland	
12	Raised marine terraces with a shallow mantle of Waimihia Lapilli overlying more weathered tephra	
13	Low hills with a mantle of Taupo airfall tephra overlying coarse lapilli	
14	Terraces formed from Taupo flow tephra and volcanic alluvium	
15	Greywacke mountain and hill country with a mantle of Taupo airfall tephra	
16	Uplands and mountainlands with a mantle of highly erodible tephra	

Icl, Iwl, Ilel, IIwl, IIIwl, IIIw2, IVwl, VIwl, VIIwl
IIIs2, VIs3, VIIsl
IIIs4, VIs2
IIIs5, IVsl, VIel3, VIIeB, VHIel
VIe9, VIelO, VIIe6, VllelO
VIe3, Vllel, VIIIe3
VIe4, VIIe2, Vllell, VIIIe2, VIIIe3
VIe7, VIIe4, VIIIe3

VIe8, VIIe5
VIel4, VIIe9, VIIIe2, VIIIe3, VIIIsl, VIsl, VIIe8
IHsl, Illel, IVel, Vcl, VIe2, VIe5, VIIe3, VIIIe2, VIIIe3

LUC SUITE 1: ALLUVIAL PLAINS AND TERRACES

This suite consists of flat alluvial plains and terraces. They occur below 300 m a.s.l. and are usually near sea level. Main areas are the Gisborne, Wairoa and Heretaunga Plains, but also included are narrow inland valleys (Figure 11). There are 9 LUC units in the suite which covers 48,910 ha or 4.2% of the Region.

Most of the LUC units in the suite have problems of drainage, and so are subdivided according to the degree to which wetness is a limitation to productive use. This limitation (with one exception) increases from class I to class VII. Wetness is related to soil texture and structure, internal drainage characteristics, water table levels and surface flooding. Soils are deep, recent soils from alluvium, with some areas of organic soils developed from peat. Together with the increasing wetness limitation from class I to class VII, there is a change in soil texture from sandy loams and silt loams to clay loams and peaty loams.

The suite contains all of the class I and class II land in the Region, a total of 25,280 ha. This is the most productive, versatile and intensively used land. It has the best soils and most suitable climate for plant growth. Although originally used for pastoral farming, areas of class I and class II land are increasingly being used for horticulture, viticulture and orcharding.

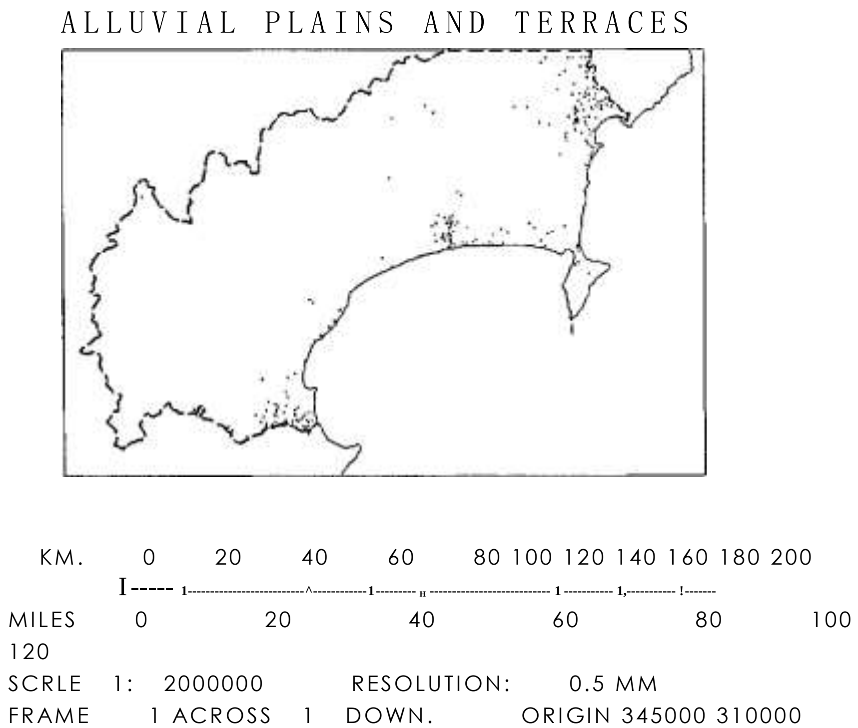


Figure 11: Location of LUC suite on alluvial plains and terraces.

Climate

The climate, particularly of the Gisborne, Wairoa and Heretaunga Plains, presents few limitations to land use. Sunshine hours are high and frosts are infrequent. Winds are generally not strong and temperatures are warm in summer and mild in winter.

The rainfall varies between 800 and 1200 mm p.a. on the plains, only exceeding 1200 mm p.a. in inland valleys. Distribution is highly variable with winter maximums and spring minimums.

Periods of drought are common. At Napier the average duration per drought is 56 days, while droughts of up to 150 days have occurred. At Gisborne the average duration is 54 days with a maximum of 120 days (Grant 1968). However the effects of drought in this suite are correspondingly less than those in other suites due to the ability of the soil to retain water. Although rainfall is usually sufficient for plant growth, irrigation is necessary during summer for intensive horticultural use.

The mean annual temperature is 13.5-14.5°C, and although there is a wide range of temperature extremes the climate is regarded as among the warmest in New Zealand. Sunshine hours on the plains vary from 50% of the possible at Wairoa to 53% at Napier.

At Gisborne the prevailing wind is north-westerly, being channelled down the Gisborne Plains. The main wind directions are from the north and south at Wairoa, the northerlies being channelled down the Wairoa Valley. At Napier winds are predominantly west to south-westerly. All areas experience daytime sea breezes. Strong winds are not common, with conditions calm for 25% of the time at Gisborne, 27% of the time at Wairoa and 32% of the time at Napier.

Frosts are infrequent, with an average of 8.8 screen frosts/year at Napier, 5.1 at Wairoa and 6.8 at Gisborne. This low incidence of frosts, together with warm spring-summer temperatures, high sunshine hours and lack of wind, makes these areas suitable for a wide range of crops. Climatic data on inland valleys are sparse, but as most of these are within 20 kms of the coast and usually adjacent to the major plains, conditions are likely to be similar.

Rock Type

The rock type is alluvium, comprising flood plain deposits usually of sand size or finer material and usually of Recent age (Crippen and Eyles 1985). Also included are areas of peat, although these are limited in extent and are usually mapped in association with alluvium. Underlying these deposits of alluvium on the plains are gravels, but at sufficient depth to have no effect on land use.

The plains and terraces have been formed during the last 10,000 years from river deposited sediments. These alluvial sediments vary somewhat in nature, depending upon the materials within the catchment from which they have been derived. Chief sources of these sediments are mudstones, siltstones and sandstones.

Rhyolitic tephra is a significant component of alluvial sediments in the north of the Region, particularly on the Gisborne and Wairoa Plains. It has been eroded and subsequently deposited along with other sediments, or deposited as airfall tephra to form thin beds within the alluvium. Near the coast at Napier the alluvium included marine as well as fluviatile sediments.

On the plains the alluvium tends to become finer in texture towards the east, with increasing distance from source, and also finer with increasing distance from the major river beds. This is because during floods the coarser materials are deposited first. Prior to European development of these plains and terraces the alluvium was actively accumulating through addition of sediment at times of flood. Today much of the Gisborne and Heretaunga Plains is protected from such flooding by stopbanks and other river control works. However significant areas, particularly narrow alluvial terraces in hill country, are still subject to flooding and addition of sediment.

Soils

The LUC units in this suite are defined according to the degree of wetness and drainage characteristics of the soil, since these are the major limitations to land use. For these reasons land use capability can be identified on the basis of soil type (or occasionally soil series). Soils in the suite are classified as recent soils from alluvium or, occasionally, organic soils. They are deep and fertile and range from well drained at the class I level to very poorly drained at the class VII level. The degree of wetness is reflected by the amount of gleying or mottling, the water table level and by soil texture. Soil wetness increases as textures change from sandy loams and silt loams to clay loams and peaty loams.

The area over which the suite extends is covered by a number of soil surveys. Soils of the inland valleys are from the General Survey (New Zealand Soil Bureau 1954) in the north of the Region and from the Mid Hawke's Bay Survey (Pohlen *et al.* 1947) in the south, while the central area has been mapped using soils from the Wairoa County Survey (Rijkse unpublished). The major plains have been covered by more detailed soil surveys. These are the Gisborne Plains Survey (Pullar 1962) and the Heretaunga Plains Survey (Department of Scientific and Industrial Research 1939). The Wairoa Plains have been mapped at 2 miles:l inch (1:126,720) by Pullar and Ayson (1965). Although information from this report was used in the NZLRI the soils recorded for this area are from the more recent Wairoa County Survey (Rijkse unpublished) which is at a scale of 1:63,360.

Topography

All LUC units in this suite occur on flat alluvial plains and terraces, but there are a number of different physiographic locations. Classes I, II and III occur on broad plains; classes III and IV on narrow elongated terraces surrounded by hills; classes IV and VI on lake and lagoon margins and class VII on swamps. All are at present river level.

Although the Gisborne, Wairoa and Heretaunga Plains are essentially flat, in each case there is a slight fall towards the coast. At Gisborne this averages 1.4 m/km from Te Karaka, at Napier 1.6 m/km from near Fernhill and at Wairoa 2.7 m/km from Frasertown. There are also slight rises and falls across the plains. The rises correspond to past or present positions of the rivers, which deposit much of their sediment in the vicinity of the river course. Depressions between these rises are often more poorly drained, and this is further aggravated by a build up of fine sediments during times of flood, so that these soils have a high clay content. In general the more poorly drained soils, especially on the Gisborne and Wairoa Plains, occur towards the margins of the plains away from the major rivers, while the better drained soils are in the centre of the plains.

Terraces in narrow valleys are generally poorly drained. They are subject to frequent flooding in many cases, and receive runoff from surrounding hills. At the base of these hills there is usually a build up of colluvial material which is the product of erosion further up slope. These colluvial fans extend out onto the terraces. The meandering nature of the streams can create problems of access, especially for more intensive uses.

Erosion

There is no erosion hazard for the majority of the suite. There is however a potential for streambank erosion of terraces in narrow valleys. This potential is normally slight but may be locally severe. Much of the broad plains area is without significant streams, and drainage is by a system of drains. The major rivers may be subject to minor streambank erosion.

Deposition of sediment during times of flooding is common on terraces in narrow valleys. On the plains deposition has been largely controlled by a system of stopbanking and overflow channels.

Under a grassland cover soils do not erode, however there is one LUC unit which has a potential for slight to moderate wind erosion when cultivated. Ilel is mapped where deep layers of fine sand and silt have been deposited during relatively recent floods. The result is a loose, weakly developed, sandy topsoil which is readily blown by wind.

Vegetation

As this suite contains the most intensively used land in the Region the vegetation consists almost entirely of high producing pasture or crops. Rushes are common within the pasture in the more poorly drained areas, and as the wetness increases sedges also become significant. In swamps and on lagoon margins raupo, flax, sedges and other swamp species occur.

Although pasture is the dominant vegetation the area in crops has increased dramatically in the ten years since the survey was carried out. There has also been an increase in the range of crops grown, with a concentration on subtropical fruit, particularly kiwifruit. The actual area of crops at the time of the survey cannot be estimated because at the scale of mapping inventory units normally contained a combination of pasture and crops in which pasture was

Table 18: Production data for LUC units on alluvial plains and terraces

normally dominant (65% of the suite). Only where large continuous areas of crops were grown were they the major vegetation within an inventory unit (9.5% of the suite). Scrub and forest are almost entirely absent from this suite, trees occurring only in the form of orchards and shelterbelts.

Land Use and Land Management

Land use in this suite is a mix of pastoral farming and cropping, with cropping concentrated on the class I and II land on the Gisborne and Heretaunga Plains. Traditionally this has consisted of cereal cropping, mainly maize, orcharding and some market gardening. Recent trends have seen an increase in the range of crops being grown. Orchards, vineyards and subtropical crops, particularly kiwifruit have increased at the expense of pastoral farming and cereal cropping. Even in some of the narrow valleys away from the main plains some cropping is being tried. However because of poor drainage, potential for flooding, distance from markets and limited area, cropping here is only used as a supplement to income from pastoral farming.

Land management practices centre around drainage, and in the case of cropping, irrigation and shelter as well. Drainage is necessary to improve production on all but LUC units Icl, Iwl, and Ilel. This normally takes the form of tile or open drains (Figures 17, 19). In narrow river valleys terraces are subject to runoff from surrounding hills. To prevent this drains should be dug at the base of these hills. Irrigation is needed on class I and II land used for horticulture or orcharding. Shelter is necessary to prevent wind erosion only on LUC unit Ilel. However shelter should be provided wherever cropping is practised to improve climatic conditions for plant growth.

Where there is a potential for streambank erosion streams should be protected by tree planting, particularly with willows. Such areas normally occur in narrow valleys. Flooding and deposition have been largely controlled on the major plains by river control works, however on terraces in narrow valleys such control is not practical and flooding and deposition may be common. Control in these cases lies further upstream on the steep slopes of the catchment.

Land Use Capability Units

Each of the 9 LUC units in this suite is defined by the degree to which wetness is a limitation to productive use. The 'level' of wetness for each LUC unit is summarised in Table 17.

This 'level' of wetness affects both the range of plants that can be grown and the productivity of those plants. In Table 18 a measure of this versatility and productivity is given for each LUC unit. There is a general decrease in both versatility and productivity from class I to class VII.

Table 17: Wetness characteristics related to LUC units on alluvial plains and terraces

LUC Unit	Water Table	Internal Drainage	Soil Group	Surface Flooding
Icl	Does not affect production	Well drained	Recent alluvial	Nil
Iwl	Does not affect production	Well drained	Recent alluvial	Nil
Ilel	Does not affect production	Well drained	Recent alluvial	Frequent
IIwl	In subsoil in winter	Moderately well drained	Recent alluvial Gleyed recent	Ponding
IIIwl	Fluctuating near surface in winter	Imperfectly to poorly drained	Recent alluvial Gleyed recent	Infrequent
IIIw2	Fluctuating	Moderately well drained	Recent alluvial	Frequent
IVwl	At surface in winter	Poorly drained	Organic soils	Frequent
VI wl	Some surface water in winter	Very poorly drained	Organic soils	Frequent

LUC Unit	Stock Carrying Capacity (SU/Ha) Present Average	Top Farmer	Attainable Potential	Site Index for *P. radiata* (m)	Cropping Potential
Icl	20	25	32	33 +	Wide range including: stonefruit, pipfruit,
Iwl	17	25	32	33 +	subtropical fruit, citrus, grapes, berryfruit,
Ilel	15	15	20	35 +	vegetables, cereals, root and green fodder crops
IIwl	18	25	30	33 +	Pipfruit, some subtropical fruit, citrus, grapes, berryfruit, most vegetables, cereals, root and green fodder crops
IIIwl	12	17	26	30-32	Some vegetables, cereals, root and green fodder crops
IIIw2	11	15	17	Unsuitable	Cereals, root and green fodder crops
IVwl	10	12	15	Unsuitable	Root and green fodder crops
VIwl	5	5	12	Unsuitable	Unsuitable

Table 19 shows typical yields of maize in tonnes/ha for the arable units found on the Wairoa Plains.

Table 19: Maize yields for selected LUC units on alluvial plains and terraces

LUC Unit	Tonnes/ha
Icl	11.2-12.4
Iwl	10.0
IIwl	9.4
IIIwl	9.4
IIIw2	10.0

Although it may be possible for yields to be increased beyond these levels the figures do show a general decrease from class I to Class III. The high figure for IIIw2 is due to the fact that the LUC ranking relates more to the flooding risk than to the poor drainage of the soil.

LUC unit Icl (4,410 ha)—Figures 12, 63

Land classified as Icl has only minimal limitations to use. Soils are deep and fertile with a high moisture holding capacity. The free draining nature of the soils and the location of Icl means there is a negligible wetness limitation. Therefore, although all the arable units in this suite have a climate suitable for growing a wide range of crops, because of a lack of other limitations to use in this LUC unit, the climate is the only restricting factor. Rainfall is usually 800-1000 mm p.a. and with periods of drought common during summer, irrigation is required for some crops. Although erosion is negligible, provision of shelterbelts is common to improve crop production.

Icl occurs on the main alluvial plains usually adjacent to river courses. Soils include Matawhero silt loam and Waihirere silt loam on the Gisborne Plains, Waihirere soils on the Wairoa Plains and Twyford sandy loam and Hastings silt loam on the Heretaunga Plains. Much of Icl is used intensively and crops include pipfruit, stonefruit, citrus, grapes, kiwifruit and other subtropical crops, process vegetables, market garden vegetables and cereals. There is still a significant area used for grassland farming, although this has decreased since the survey was carried out. The potential stock carrying capacity is 32 su/ha and the site index for *P. radiata* is 33+ m, both figures equal to the highest in the Region.

Table 18: Production data for LUC units on alluvial plains and terraces

LUC unit Iwl (6,700 ha)—Figure **13**

This unit is usually found in association with Icl and is similar in its present and potential land use, although a larger area is used for cropping. There is however a very slight wetness limitation due to the slightly heavier and more compact nature of the soils. Soils include Matawhero heavy silt loam, Waihirere silt loam, mottled subsoil phase, Waihirere heavy silt loam and Twyford silt loam and loam. Drainage is slightly slower than in Icl with faint mottling of the subsoil. However the soil is able to retain moisture for longer periods than is the case for Icl. Despite this, irrigation is still required in summer for optimum production. Potential stock carrying capacity and site index for *P. radiata* are the same as for Icl.

LUC unit Ilel (3,430 ha)—Figures **14, 15**

Although this unit occurs on low river terraces with deep recent soils from alluvium it is a little anomalous in this suite in that all the other **LUC** units are classified and arranged in capability order on the basis of 'wetness'. In the case of Ilel erosion and soil moisture deficiencies rather than wetness are the main limitations to use.

The unit is found along the banks of the Ngaruruoro and Tutaekuri rivers where they flow out of the hills onto the Heretaunga Plains, in the lower reaches of the Esk Valley and in a number of other small valleys north of the Esk River.

The soils are Esk sand or Twyford sandy loam, shallow phase and have developed from fine sand and silt deposited during relatively recent floods. In the Esk Valley much of this sediment was deposited during a severe flood in **1938.** It was estimated that the Esk River rose between **9** and **12** metres and deposited sand and silt up to **3** m deep in places (Hill **1938).** As a result the soil is light and poorly structured, though of moderate natural fertility. It dries out rapidly in summer, necessitating irrigation especially for shallow-rooted crops. Buried soils occur beneath approximately **1** m in the case of Esk sand.

The sandy texture and poor structure of the topsoil creates a potential for slight to moderate wind erosion when cultivated. Where regular cropping is practised windbreaks are necessary, and in the case of grapevines the use of grass strips between rows will further reduce the wind erosion hazard. There is also a risk of further flooding and deposition, especially in narrow valley situations.

This unit is suitable for a wide range of crops with its favourable climate and deep free-draining soil. In recent years much of the unit has been planted in grapevines, a crop particularly suited to these conditions. Site index for *P. radiata* is very high at **35+** m while the potential stock carrying capacity at **20** su/ha reflects restricted pasture growth during summer.

LUC unit IIwl (10,740 ha)—Figures **16, 42, 43**

IIwl occurs on the broad coastal plains of the Region and also in some of the wider river valleys such as at Nuhaka. Here there is an increase in the wetness limitation which leads to a slightly more restricted range of crops which can be grown.

Soils include Matawhero clay loam, Waihirere clay loam, Kaiti silt loam and Pakowhai clay loam. These soils are still deep and fertile but they are also heavy, have a relatively high water table and moderately slow subsoil drainage. Nevertheless topsoils may dry out and crack during summer. Drainage is necessary on these soils to lower the water table and carry away ponding water after rain. Even after drainage however, there is still a slight wetness limitation.

The major uses on IIwl are cereal cropping (maize) and pastoral farming, although some horticulture, viticulture and orcharding does occur. Drainage and shelter would make this unit suitable for more intensive cropping. The potential stock carrying capacity is **30** su/ha while site index for *P. radiata* is **33+** m.

There is a potential for some streambank erosion, flooding and deposition along river valleys.

The unit also includes slightly saline plains at Meeanee near Napier. This area was a saline estuary before the 1931 Napier earthquake, but with the uplift and subsequent use of drains salinity has been reduced. Today, although the groundwater is quite saline, there is little effect on the range of crops that can be grown. Soils are those of the Farndon series. Nearer the coast, where there is a slight increase in wetness and salinity, soils are those of the Meannee series. These areas have been included in IIIwl.

LUC unit IIIwl (17,900 ha)—Figures 17, 35, 49, 50

This unit occurs in two different positions in the landscape. The first is on broad plains where soils have moderately high water tables and poor internal drainage. The second is in narrow river valleys where there is also the problem of runoff from surrounding hills, flooding and the potential for streambank erosion. (These two different situations warrant two separate IIIw units, and in a correlation of LUC units in the 10 regions in the North Island (Page 1985) IIIwl has been correlated with both IIIw units in narrow valleys and IIIw units on broad plains from other regions.)

Soils include Makaraka heavy silt loam and clay loam, Makauri clay loam, Kaiti heavy silt loam and clay loam and Awamate silt loam. These soils occur in depressions, making drainage difficult. Water tables are as high as 30 cm from the surface during winter but topsoils dry out and crack badly during summer. Topsoil structure is moderately to strongly developed and natural fertility high. Mottling is apparent in the subsoil.

Much of IIIwl is used for grassland farming and maize growing with some market gardening. Because of soil wetness the unit is not well suited to orchards and vineyards. Soil wetness also limits early cropping. The potential stock carrying capacity is 26 su/ha and the site index for *P. radiata* is 30-32 m.

LUC unit IIIw2 **(3,620 ha)—**Figure 18

Areas of the plains subject to flooding and deposition from major rivers are mapped as IIIw2. Such areas occur on the Gisborne Plains adjacent to the Waipaoa River and on the Wairoa Plains adjacent to the Wairoa River. They are areas either presently at risk of flooding or that have been flooded in the recent past. Soils belong to the Waipaoa series. These are rapidly accumulating soils which are low in organic matter (Pullar 1962). Below about 45 cm there are a series of buried soils, often more friable and better drained than the present topsoil which has a weakly developed structure, poaches in winter and dries out and cracks in summer. Hence although there are soil limitations related to structure and fertility, the main limitation is one of wetness, both from flooding and also the poor natural drainage of the soil.

The unit is used for grassland farming and maize, although those areas within the floodway of the Waipaoa River are unsuitable for arable use. Potential stock carrying capacity is down to 17 su/ha and the unit is unsuitable for production forestry because of the risk of flooding and wetness.

LUC unit IVwl (1,150 ha)—Figure 19

East of Wairoa are a series of lagoons formed in an alluvial basin behind a narrow belt of coastal dunes. The wettest margins of these lagoons are mapped as VIwl and slightly higher areas behind VIwl are mapped as IVwl. Another area of IVwl occurs in a series of narrow valleys behind Fernhill on the edge of the Heretaunga Plains. Two such areas are the margins of Runanga and Oingo Lakes. All these areas of IVwl are characterised by a mixture of peat and alluvium with high water tables to within 30-50 cm of the surface. During winter water tables may reach the surface. The typical soil texture is a peaty loam.

Near Wairoa the soils are mapped as Pongakaawa series and near Fernhill as Poukawa series. These are organic soils with moderate soil structure and high natural fertility. With drainage there is still a severe wetness limitation to arable use.

The unit is at present intensively grazed with a mixture of high and low producing pasture and rushes. Much of the area near Wairoa has been drained, using a system of pumps and tile drains, and is now used for growing maize. Potential stock carrying capacity is 15 su/ha, while the degree of wetness makes the unit unsuitable for production forestry.

IVw2 occurs at 1000 m a.s.l. between the Kaweka and Kaimanawa Ranges and, because of factors such as climate, parent material and vegetation, is described in conjunction with the suite of units in that area (LUC suite 16).

LUC unit VIwl (660 ha)—Figures 20, 21

VIwl is mapped on the margins of a series of lagoons just east of Wairoa. The largest of these is Whakaki Lagoon. The area is flat and low lying, receiving runoff from surrounding hills. The margins of the lagoons are therefore naturally wet with mixed pasture/rush/sedge vegetation, despite the presence of drains. Added to this is the fact that the outlets from these lagoons are narrow and pass through the coastal foredunes. These outlets are blocked most of the time and need to be mechanically opened 3-4 times per year. During storms backing up of stormwater increases the size of the lagoons considerably, inundating the surrounding areas of VIwl and IVwl.

High water tables throughout the year, together with the potential for frequent flooding, make these areas unsuitable for cropping or forestry. Use is limited to grazing, where the potential stock carrying capacity is 12 su/ha.

LUC unit VIIwl (300 ha)—Figure 22

Unlike all of the other units in this suite VIIwl occurs in upland areas between 800-1000 m a.s.l. where rainfall is 2000-2500 mm p.a. The unit occurs in two areas, just north of Lake Waikareiti in the Urewera National Park, and at the head of the Taharua River on the southern margin of the Rangitaiki Plains. It is included in this suite because of its wetness limitation, although it is not part of the sequence formed by the other units.

The area near Lake Waikareiti, known as Kaipo Lagoon, is a peat bog. It is composed of peat and volcanic ash (Lowe and Hogg 1986), and supports a pakihi type vegetation of rushes, *Gleichenia* fern and sphagnum moss. There is surface water for much of the year and drainage of this area would be impractical. It is the largest of a number of peat bogs and wetlands in the area, the remainder of which were too small to map.

The area in the Taharua catchment consists of shallow peat on Taupo flow tephra. It is situated at a low point on an extensive terrace of flow tephra and is drained by the head of the Taharua River. The area is undeveloped, consisting of swamp vegetation and *Dracophyllum.* Drainage of this area would lead to gullying within the flow tephra.

VIIwl is unsuitable for production forestry and has a potential stock carrying capacity of only 5 su/ha.

Figure 12: Icl. Apple orchard. State highway 50, near Fernhill. N134/210294, looking south.

Figure 13: Iwl. Vegetables. Pakuratahi Valley, south of Tangoio. N124/326566, looking west. VIe2 hills in background (LUC suite 10).

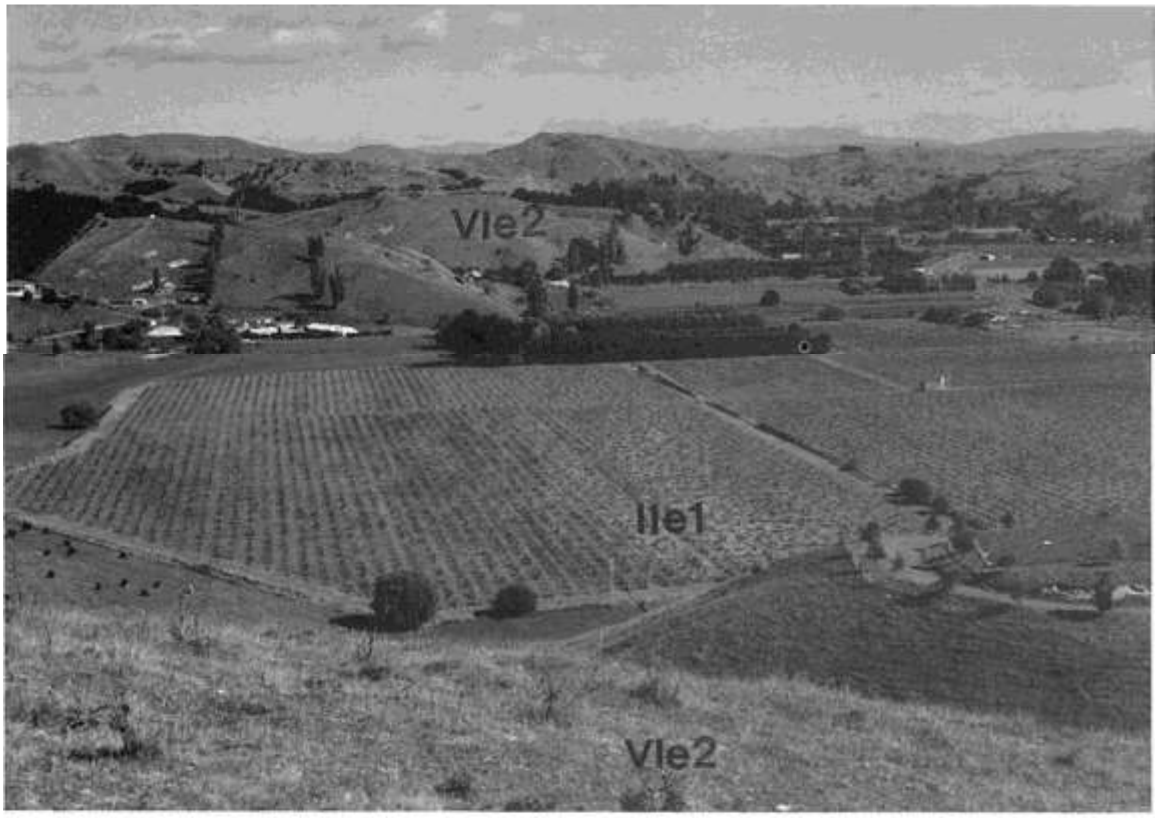


Figure 14: IIe1. Vineyards. Esk Valley. N124/275505, looking north-west. VIe2 hills in left centre (LUC suite 10).

Figure 15: IIe1. Bank exposing Esk sand. Note dark grey buried topsoil. VIe5 hills in background (LUC suite 10).

Figure 16: IIw1. Recently established apple orchard between rows of sweet corn. Near Napier-Hastings motorway. N134/276314, looking south-east.

Figure 17: IIIwl. Narrow river valley, note drains. From Wairoa Hill. Nl 16/845946 looking south-east. Surrounding hills are VIe7 (LUC suite 8).

Figure 18: IIIw2 on the Gisborne Plains. The unit occurs between the stopbanks surrounding the Waipaoa River. N98/299448, looking north. Photo: East Cape Catchment Board

Figure 19: IVw1 after heavy rain. East of Wairoa, near Whakaki Lagoon. N116/895934, looking west.

Figure 20: VIw1. Near Whakaki Lagoon. N116/898925, looking south.

Figure 21: VIwl after heavy rain. Flooding is aggravated by blocked lagoon outlets Near Whakaki Lagoon. Nl 16/898925, looking south.

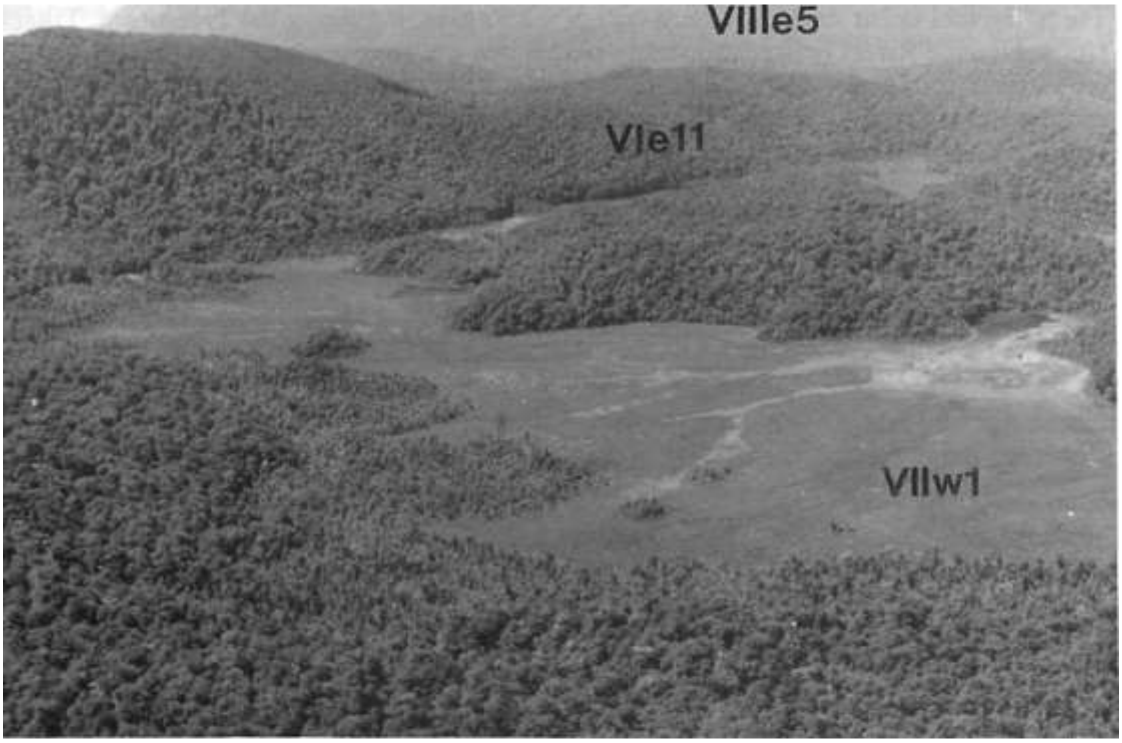


Figure 22: VIIwl. Kaipo Lagoon, Urewera National Park. N96/608375, looking south-east. Forested low hills are VIell and steep range in background is VIIIe5 (LUC suite 11). Photo: N A Trustrum

LUC SUITE 2: GRAVEL TERRACES

This suite comprises terraces, where the presence of gravels has an effect on land use. These terraces occur in the southern part of the Region, bordering the Ngaruroro, Tutaekuri and Mangaone Rivers between the main ranges and the Heretaunga Plains (Figure 23). They are formed from greywacke or sandstone gravels which may occur at the surface or as stony subsoils as far as 80 cm beneath the surface. The older and higher terraces have the greatest soil depth, and it is this depth to gravels which determines the land use capability. Limitations are low soil moisture holding capacity, shallow rooting depth and low fertility.

The area of the suite is 6,860 ha. It occupies 0.6% of the Region and comprises 3 LUC units, IIIs2, VIs3 and VIIsl.

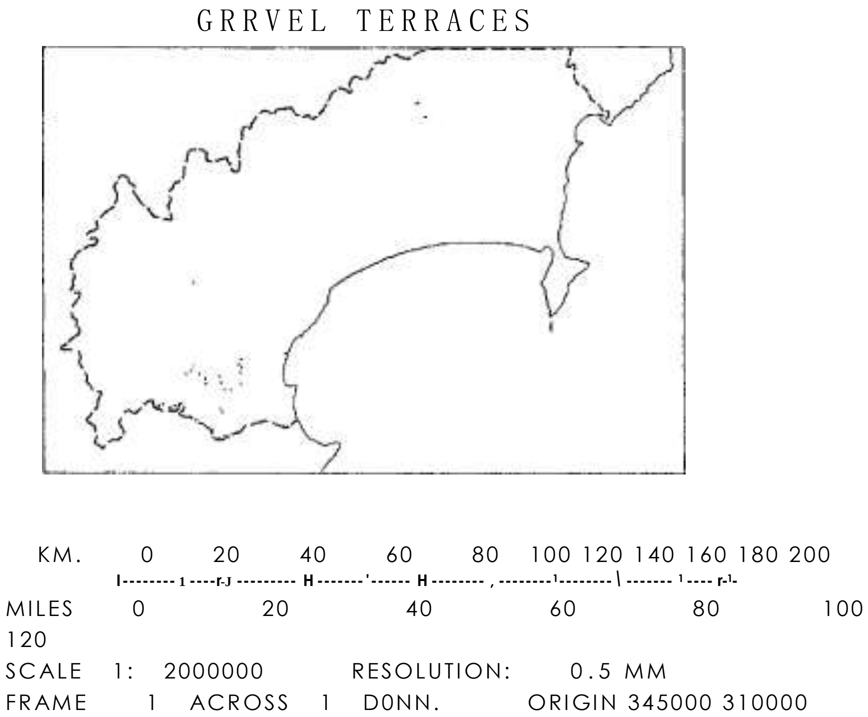


Figure 23: Location of LUC suite on gravel terraces.

Climate

This suite occurs where the annual rainfall is both low and variable. Near the Heretaunga Plains the rainfall is 800 mm p.a., while at Rissington and Whanavvhana it is 1200 mm p.a. Several small areas occur further inland where the rainfall reaches approximately 1500 mm p.a. The distribution of this rainfall is characterised by frequent lengthy droughts. These may be up to 3-4 months in duration, and their effects are accentuated by the free-draining nature of the gravels. Rainfall has a winter maximum and a spring minimum, with greatest variability during spring-summer. Under these conditions irrigation is necessary if cropping is to be carried out.

Summers are very warm and winters are mild with between 40-70 ground frosts per year. The area experiences a high number of sunshine hours and is less windy than areas on the west coast. Both these features result from the protection afforded by the main mountain ranges to the west. Nevertheless wind is not uncommon and is predominantly from the west to south-west. Warm dry winds occur in spring and summer; these have a drying effect, reducing soil moisture available to plants.

Rock Type

During the glaciations of the late Pleistocene large quantities of gravel were deposited by rivers as a result of erosion in the main ranges. The rivers subsequently cut down into these surfaces following a drop in sea level, to leave terraces which today are 20-80 m above river level. The terraces are composed of greywacke gravels, which are only slightly weathered, and scattered pumiceous sands (Kingma 1971). Below these terraces, at present river level, are small areas of recently accumulating gravels. In the case of these lowest terraces the gravels are at the surface, while the older and higher terraces have a greater degree of soil development and have also had various additions of loess and tephra.

Soils

Soils developed on the lowest most recent terraces are very stony and are classified as recent soils from alluvium. They are typically Tukituki gravelly sands or Tukituki stony gravels. On the older higher terraces soils are deeper and are classified as intergrades between yellow-brown loams and yellow-brown earths. These soils belong to the Takapau series, the main soil types being Takapau sandy loam and Takapau silt loam. Except for two small areas near the ranges the soils are from the Mid Hawke's Bay Survey (Pohlen *et al.* 1947).

The soils in this suite are light textured, stony, have rapid drainage, and are prone to seasonal soil moisture deficiencies. It is a combination of these factors which provide the major limitations to land use.

Topography

The terraces border the major rivers and have an elongated form. They are flat or gently sloping and in some areas have been dissected to form a series of small terraces separated by entrenched streams. These higher terraces are normally backed by downlands or low hills. The low stony terraces are adjacent to the river and are at or near present river level, having been part of the river's course in the recent past.

Erosion

Although erosion is not a major problem in this suite the potential does exist for slight erosion on all 3 LUC units. Because of the light, friable, sandy soils areas that are cultivated are susceptible to wind erosion. However under a pasture cover erosion is negligible. On low terraces that border rivers there is a potential for streambank erosion, and where these terraces are susceptible to flooding, deposition of sediment may also occur.

Vegetation

Except for a limited amount of cereal cropping where the soils are deeper, and occasional manuka on the stonier terraces, the vegetation of this suite is almost entirely pasture. The pasture on the deeper soils consists of dominantly high producing species. With an increase in stoniness and a decrease in soil depth there is a corresponding increase in low producing species and weeds until, on terraces at river level where stones lie on the surface, the pasture includes plants such as foxgloves, flatweeds, lupins, etc, together with areas of bare ground.

Land Use **and** Land Management

Land use is restricted to pastoral farming, although on the older higher terraces where soils are deeper there is a potential for cropping. On the higher terraces grazing is intensive, while on the lower, stonier terraces it is extensive.

Irrigation is necessary if the summer soil moisture deficiencies which affect plant growth are to be overcome. On the better pastures some sprinkler irrigation is already practised. On similar areas just south of the Ngaruroro River in the Southern Hawke's Bay-Wairarapa Region border-dyke irrigation is practised. Any intensive cropping would require some form of irrigation.

These terraces, being situated adjacent to major rivers, are exposed to winds which are funneled down these valleys. Although stable under a pasture cover, when cultivated the light, friable, droughty soils are susceptible to wind erosion. For this reason (and also for general stock protection) shelterbelts are necessary if cropping becomes a major land use. At present only terraces between Matapiro and Whanawhana, near the north bank of the Ngaruroro River, have significant shelterbelts. Similar areas on the Takapau Plains, in the

Southern Hawke's Bay-Wairarapa Region, have been planted with shelterbelts, after cropping in the past led to significant wind erosion.

Land Use Capability Units

In this suite the major limitations to use occur within the soil. The LUC units are defined on the basis of:

1. The depth of soil above gravel. This determines rooting depth and affects the moisture available for plant growth.

   The soil moisture deficiencies experienced in this suite are caused not only by the poor water holding capacity of the soil but also by the presence of summer droughts.

2. Stoniness. Both density and size of gravels, stones or boulders determines the ease of cultivation and the soil volume.

The criteria used to assess land use capability in this suite are summarised in Table 20, and illustrated diagrammatically in Figure 2<.

Table 20: Criteria used to assess LUC units on gravel terraces

LUC Unit	Depth of Soil	Degree of Stoniness	Susceptibility to Flooding
IIIs2	30-80 cm	Stony subsoil. Small stones may be present throughout profile	Nil
VIs3	<15 cm	Stones at surface and throughout profile	Medium
VIIsl	<15 cm	Large stones at surface and throughout profile	High

LUC unit IIIs2 (5,610 ha)—Figure 25

This LUC unit occurs on the higher terraces where there is between 30-80 cm of free-draining, light textured soil over gravels. Although gravels may occur throughout the profile they do not affect cultivation. Soils belong to the Takapau series and are silt loams, sandy loams or stony sandy loams. The unit is capable of being cropped, although irrigation and shelterbelts would be necessary. At present the land is intensively grazed but it is well suited to cereal crops (wheat, barley), lucerne, grapes, berryfruit and root and green fodder crops. Although natural fertility is low the soils respond well to fertiliser. There is a high stock carrying capacity of 23 su/ha and a site index for *P. radiata* of 25-30 m. Terraces are flat and without erosion risk except when cultivated, in which case there is a potential for slight wind erosion.

LUC unit VIs3 (610 ha)—Figure 25

On lower more recent terraces the depth of soil is less than 15 cm and stones are larger and more numerous than in IIIs2, occurring throughout the profile and on the surface. Such areas are unsuitable for cropping and are mapped as VIs3. They are restricted to small areas on the banks of the Ngaruroro, Mohaka and Ruakituri Rivers. As the terraces are near river level they are liable to occasional flooding and deposition and may even be subject to some streambank erosion. Stone picking may allow occasional root and green fodder crops to be grown. However more stones will be brought to the surface at each cultivation.

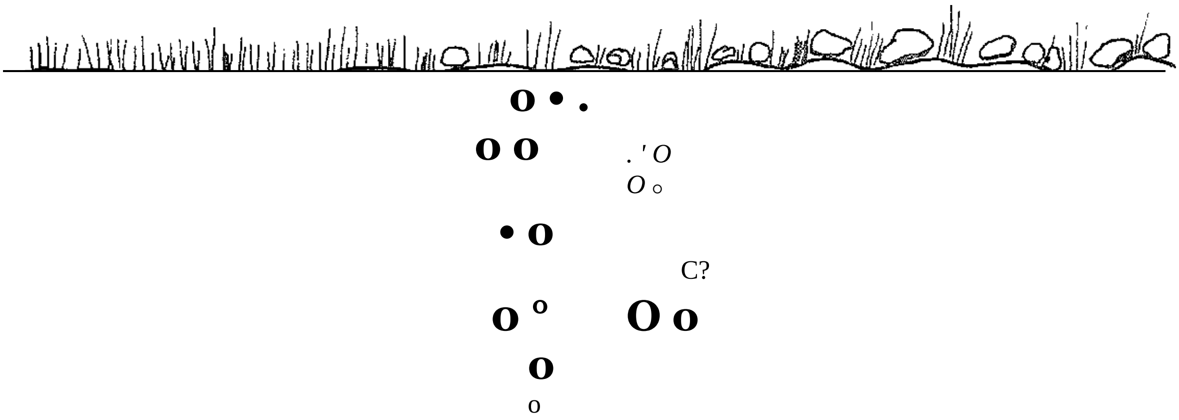
Soils belong to the Tukituki series, and typically include Tukituki gravelly sands—an excessively drained recent soil from alluvium. With the increase in gravels in VIs3 there is a corresponding decrease in moisture holding capacity. As a result pastures dry off more rapidly in summer than on IIIs2 and potential stock carrying capacity figures are low at 10 su/ha. The drop in site index for *P. radiata* to 23-28 m is not as dramatic, since tree roots extend much deeper into the gravels and extract water beyond the reach of pasture plants.

An area of gravel terraces near the Mohaka River includes some deposits of coarse, free-draining pumice alluvium.

LUC unit VIIsl (640 ha)—Figure 26

The lowest stoniest terraces bordering the Ngaruroro River are mapped as VIIsl. The terraces have been part of the river bed in the recent past and are still subject to frequent flooding and deposition. Here the soil is Tukituki stony gravels which is very stony throughout the profile with large stones and boulders on the surface. This soil is excessively drained and dries out rapidly in spring. As a result of these severe soils limitations vegetation is restricted to low producing pasture and weeds with some gorse and foxgloves. Production potentials are low with a potential stock carrying capacity of only 7 su/ha and a site index -for *P. radiata* of 20-25 m.

This LUC unit also includes the narrow raised shingle ridge north and south of Napier City which separates the saline former lagoon areas from the sea. This ridge has much bare ground and only small areas of herbaceous sand dune vegetation and low producing grasses. The ridge is very droughty and exposed to salt spray. It includes areas of VIIIs.



IIIs2	VIs3	VIIs1
30-80cm depth of soil over gravel or stones	Less than 1 5cm depth of soil Stones throughout profile and at the surface	Very stony, shallow soils Large stones at surface and throughout profile

Arable   Non Arable

Increase In size of stones, number of stones and their presence at the surface

Decrease in soil depth, and soil moisture holding capacity

Figure 24: Diagrammatic representation of the relationship between LUC units on gravel terraces.

Figure 25: VIs3 low terrace, IIIs2 higher terrace. Omapere Road, near Matapiro. N134/036264, looking north.

Figure 26: VIIs1. Ohiti Road. North bank of Ngaruroro River. N134/124248, looking east.

LUC SUITE 3: LOW LYING SALINE PLAINS

Saline soils are restricted to two localities in the Region. One is the area of the former Ahuriri Lagoon which was raised in the Napier earthquake of 1931, and the other is at the mouth of the Waipaoa river near Gisborne (Figure 27). Both areas are low-lying and have high water tables. Drainage and desalination have been employed to reclaim them for agricultural use. Reclamation began at Napier in 1934 and at Gisborne in 1958.

Salinity and wetness limit the productive use of this suite. The soils are otherwise of high natural fertility, and the climate is favourable for plant growth. The area of the suite is 3920 ha or only 0.3% of the Region and consists of two units, IIIs4 at Napier and VIs2 at Gisborne.

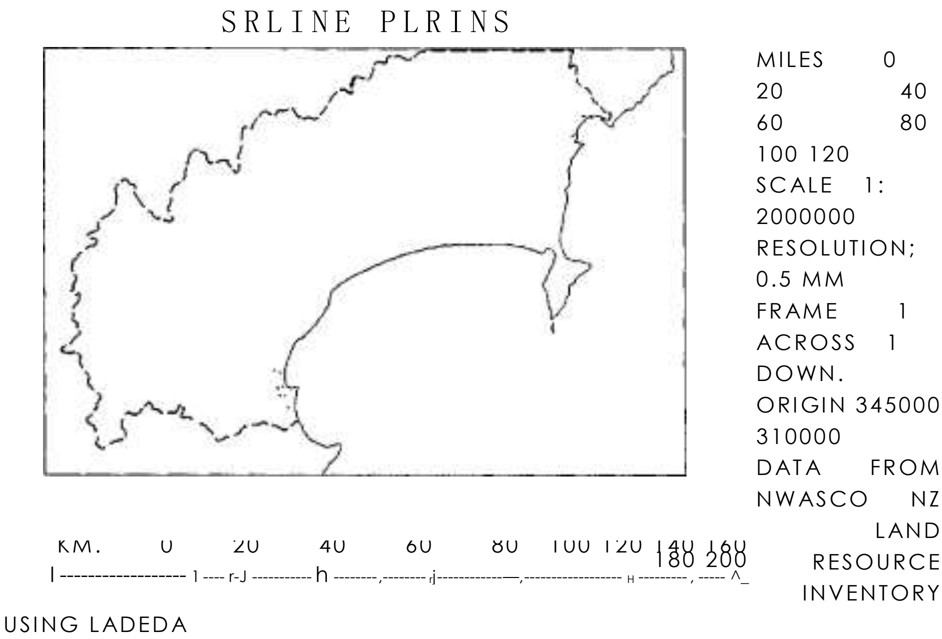


Figure 27: Location of LUC suite on low lying saline plains.

Climate

The climate of both LUC units is generally mild. At Napier the annual rainfall is approximately 870 mm, while at Gisborne it is approximately 1000 mm. In both places there is a high variability in rainfall, both monthly and annually. Frosts are infrequent with an average of only 6 screen frosts/year. The sunshine hours of both areas are high with approximately 53% of the possible sunshine.

In Gisborne the prevailing wind is north-westerly, being channelled down the Gisborne Plains. In Napier winds are predominantly west to south-westerly. Both areas experience daytime sea breezes. Strong winds are not common, with conditions calm for 25% of the time in Gisborne and 32% of the time in Napier.

Rock Type

Both areas are former lagoons that have been infilled, and in the case of the Ahuriri Lagoon subsequently raised. The rock type consists of estuarine and marine deposits of Holocene age. At Napier these deposits are of variable texture ranging from muds and silts to sands and gravels. Shell beds are also present. Much of this material has been deposited by the Tutaekuri river. At Gisborne the material is more uniform, consisting mainly of mud which has been derived from the surrounding hill country and deposited by the Waipaoa River.

Soils

The soils of these former lagoons and tidal flats are saline gleyed recent soils. These are soils with a high salt content and a high water table. At Napier the soils are mapped as Ahuriri soils from the General Survey (New Zealand Soil Bureau 1954). (The area has also been mapped in more detail by Grimmett and Hughes (1939). At Gisborne soils are those of the Muriwai series from the Gisborne Plains Survey (Pullar 1962). In both cases the soils are poorly drained with mottling in the upper horizons. Soil structures are poorly developed, and organic matter content is low. The soils are strongly alkaline and before reclamation supported only salt tolerant plants. Despite these properties the soils have a good supply of plant nutrients (Daly and Rijkse 1976, Pullar 1962).

Topography

Both LUC units consist of low-lying flats with only narrow outlets to the sea. There is very little natural runoff. A feature of the surface is the system of drains to remove the water that would otherwise build up.

At Napier the surface contains small depressions that are more poorly drained than the surrounding areas, and ridges of sand and gravel that are excessively drained. Several small hills, formerly islands, dot the flats. The flats are separated from the sea by a narrow gravel ridge which formerly bordered the lagoon. On the landward side the flats are backed by hills terminating in low cliffs which formed a previous coastline. The flats have a slight fall towards these hills.

The area of saline soils at Gisborne extends both north and south of the Waipaoa River mouth. Here the surface is only about 1 m above sea level, and without the variations found at Napier. The flats are separated from the sea by a narrow system of sand dunes.

Erosion

Erosion is negligible. However prior to stopbanking and river diversion some areas were subject to siltation.

Vegetation

Today most of the area is in introduced grasses, with some cropping being carried out at Napier. Crops include peas, barley and lucerne. The most saline areas still support salt tolerant plants. Before reclamation the vegetation consisted mainly of sea rush or sea aster and, in the most saline areas, glasswort with salt encrusted bare ground.

Land Use and Land Management

Both areas are used for intensive grazing, with some cropping at Napier. Because of the problems associated with developing this type of land, and the large-scale coordinated reclamation works required, this work has been undertaken by government departments. Today the Lands and Survey Department operates the Ahuriri Farm Settlement at Napier and the Awapuni Farm Settlement at Gisborne.

Both areas have undergone reclamation to reduce the salt content of the soil and to lower the water table. At Napier this consisted of straightening the course of the Tutaekuri River to bypass the former lagoon, into which it had flowed, the construction of a stopbanked channel to divert runoff from surrounding hills, and the construction of a system of gravity drains (Figure 28) approximately 1 m deep and 40 m apart to carry water to pumping stations where it is pumped into the Poraiti outfall, a 240 m wide channel emptying into Port Ahuriri Harbour (Farrell 1952).

At Gisborne tidal waters have been excluded from the Awapuni Lagoon by an automatic flood gate. A stopbank has been constructed to exclude runoff from surrounding higher areas, and drains have been constructed to carry excess water from the lagoon itself to a pumping station at the mouth of the Waipaoa River.

These reclamation techniques have resulted in improved drainage and a leaching of salt from the soil. At Ahuriri however, Daly and Rijkse (1976) have shown that while the soluble salt content of the soils is decreased by rainwater leaching during wet periods, it is increased by capillary ascent of the saline groundwater during dry periods. These fluctuations are greatest in the fine-textured soils and least in the coarse-textured soils. A further problem is seawater infiltration into the subsoils. Drainage and desalination have been in progress now for 50 years at Napier and 26 years at Gisborne. During this time there has been a dramatic improvement in the productivity of these areas. However the salt content of these soils remains a limitation to use.

Land Use Capabilty Units

Despite a favourable climate and a good supply of plant nutrients both LUC units in this suite have only a moderate productive potential and a limited range of uses. The degree of salinity restricts the range of crops that can be grown on IIIs4 and prevents cropping in the case of VIs2. Because of the combination of salinity and wetness both LUC units are unsuitable for production forestry.

LUC unit **IIIs4** (3,150 ha)—Figure 28

The bed of the Ahuriri Lagoon was raised 1.5 m by the 1931 earthquake, although some areas are still below mean sea level. Although poorly drained and saline, reclamation by a combination of drains and pumping stations has brought this area into agricultural produciton. The LUC unit extends from Napier north to Bay View, and consists of estuarine and marine deposits of variable textures, the coarsest sediments tending to occur nearest the coast. With more detailed mapping areas of Class IV and Class VI could be identified. These would include the stonier ridges and the low lying more saline areas. The soil types are Ahuriri silt loam and clay on the low lying areas which are poorly drained with high salt content, and Ahuriri stony sand on ridges and former shingle banks where drainage is more rapid and consequently salt is lost more quickly. Natural fertility of Ahuriri silt loam and clay is high with a potential stock carrying capacity of 20 su/ha. Present use is intensive grazing, although the most saline areas still support salt tolerant vegetation such as *Sarcocornia* spp. (glasswort). On areas where adequate drainage has been carried out and salt content significantly reduced, crops such as peas, barley and lucerne have been grown. The salinity of the soil makes the LUC unit unsuitable for production forestry.

Between Napier and Clive and as far inland as Taradale are soils of the Farndon and Meeanee series. The problems of salinity and high water tables have been reduced by drainage and the use of pumps, and today these soils support high producing pasture, cereal cropping, orchards and vineyards. Because wetness is now the major problem the Farndon soils are included in IIwl and the Meeanee soils in IIIwl (see LUC suite 1).

LUC unit **VIs2 (770 ha)—**Figure 29

The soils of this LUC unit are too saline for cropping. They occupy the tidal flats at Muriwai, south of the Waipaoa River mouth and also occur north of the mouth at Awapuni Lagoon. The land directly behind the foredunes is about 1 m above mean sea level and is subject to flooding at high tides, although this is prevented at Awapuni Lagoon by a flood gate. The areas are so flat and low lying that pumping is required to remove excess water and lower the ground-water table, which can reach the surface in winter.

Soils are the moderately saline Muriwai clay loam and the strongly saline Muriwai clay. Both have poorly developed soil structures, low organic matter contents and are strongly alkaline. Also included are small areas of Makaraka clay loam, saline phase, a gleyed recent soil, which is found bordering the tidal flats. Although not as saline, and with a water table which is lower than in the Muriwai soils, it has been included because of its limited area.

Because of the problems of salinity and wetness the sole use of this LUC unit is grazing. There is a potential for a stock carrying capacity of 15 su/ha.

Figure 28: IIIs4. Note salt tolerant glasswort growing in drains. Woolshed Road, Ahuriri Lagoon. N124/275405, looking north.

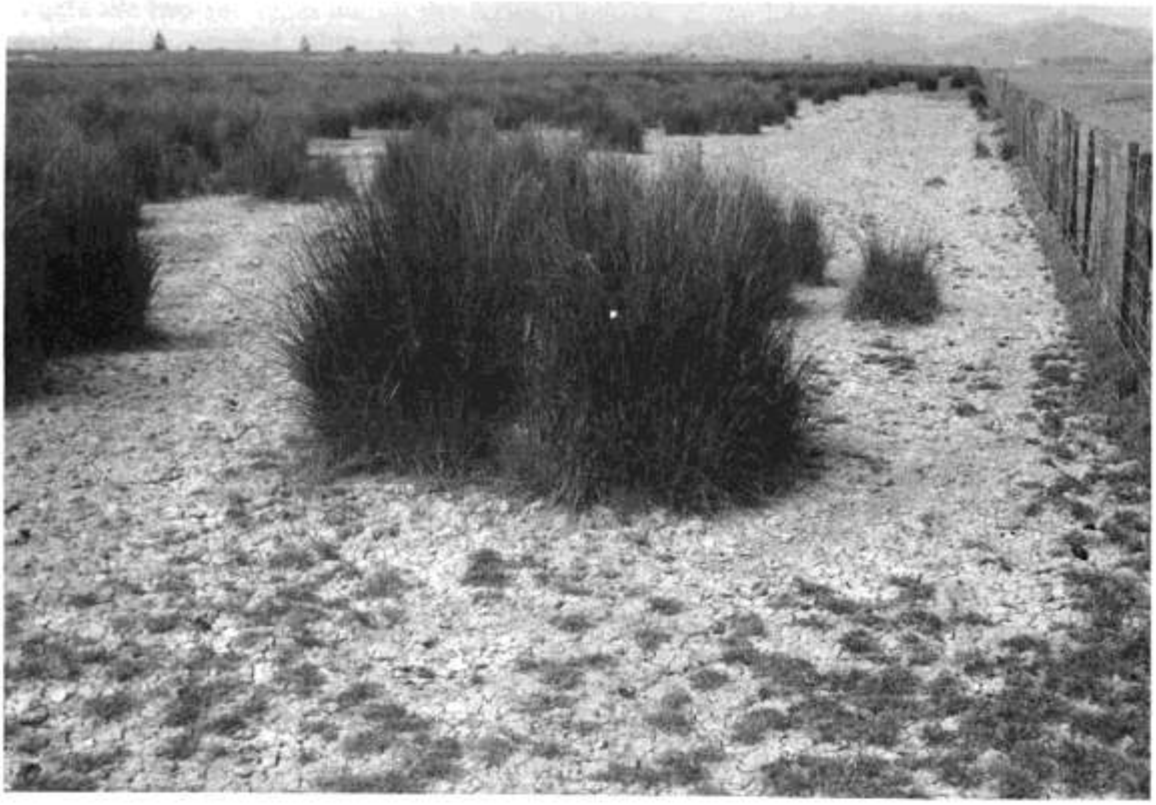


Figure 29: VIs2. Awapuni Lagoon, Gisborne. N98/354355, looking south-west.

LUC SUITE 4: SAND DUNES

A complex of sand dunes and sand plains occurs along the coast between Wairoa and Opoutama, reaching a maximum of 1 km inland at Nuhaka. From Opoutama the dunes form a tombolo 2.5 kms wide which connects Mahia Peninsula to the mainland. On Mahia Peninsula some small areas of sand dunes also occur. A further dune system occurs along the coastline of the Gisborne Plains and extends inland up to 5 km on the outskirts of Gisborne City (Figure 30). A suite of 5 LUC units have been mapped on these dune systems (Figure 31), from class III in the most stable, sheltered inland locations, to class VIII in the most unstable, exposed coastal locations. Because of the scale of mapping the sand dunes and sand plains cannot be identified separately. In such cases the LUC unit is described as a complex. The suite is a small one, occuping only 4,600 ha or 0.4% of the Region.

Land use capability in this suite is assessed on the basis of erosion potential, exposure to salt-laden winds and degree of soil development. In general dunes increase in stability, versatility and productive potential with increasing distance from the coast. This is related to the increased age of dunes further inland and therefore their degree of soil development, and a decrease in the extreme effects of wind and salt.

Only 22% of the area of the suite is presently used for pastoral farming or exotic forestry. Seventy eight percent of the suite is undeveloped, the vegetation consisting of sand dune associations dominated by lupins and marram grass.

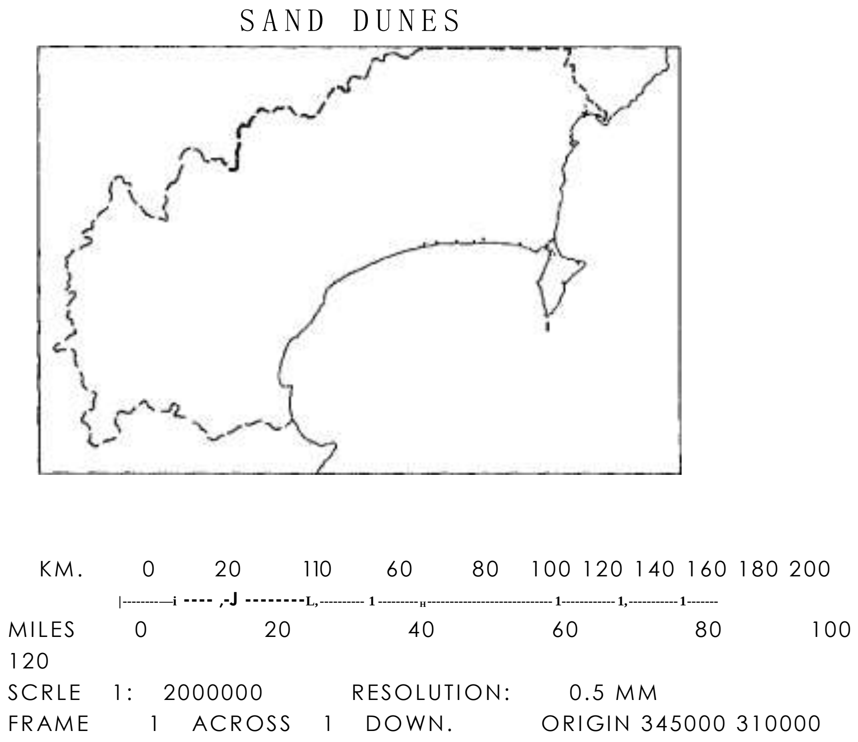


Figure 30: Location of LUC suite on sand dunes.

Climate

The climate is mild with rainfalls of about 1200 mm p.a. along the Wairoa coastline and 1000 mm p.a. at Gisborne. Droughts are not uncommon and even those of short duration are significant because of the low moisture holding capacity of the soils. The most important climatic parameter however is that of wind. Hawke's Bay and Poverty Bay are relatively sheltered and experience less windy conditions than most New Zealand districts. Predominant winds are from the north and north-west, although occasional strong southerlies do occur. At Gisborne only 12% of winds exceed 25 km/hr and 25% of the time winds are less than 5 km/hr. Despite these conditions the LUC units in this suite are susceptible to wind erosion due to the unconsolidated nature of the parent material.

Rock Type

The rock type consists of Holocene sands, mainly in the form of dunes, but including some plains. Generally the dunes further inland are stabilised or semi-stabilised, with only a narrow strip of active dunes in front which are building seaward. At Gisborne the shoreline has advanced towards the sea at an average rate of 0.2-0.8 m/yr over the last 2,000 years, but between 1883 and 1953 the rate has increased to 0.85-2.70 m/yr (Pullar and Penhale 1970). The older more stable dunes are overlain by shallow tephra.

Soils

The soils are yellow-brown sands, except in the case of the oldest most stable sands near Gisborne, where because of a mantle of rhyolitic tephra nearly 30 cm thick, the soils are classified as yellow-brown pumice soils. In the area between Wairoa and Mahia the soils are those of the Opoutama and Whakaki series, from the Wairoa County Survey (Rijkse unpublished). These soils are mapped as a soil association to reflect the close geographical relationship that exists between them. Opoutama series are mapped on the sand dunes, and Whakaki series on the sand plains. At Gisborne the soils belong to the Opoutama series or, where rhyolitic pumice overlies sand, to the Te Hapara series. These soils are from the Gisborne Plains Survey (Pullar 1962).

Soils of the Opoutama series have coarse sandy textures and are structureless. They have little topsoil development and are low in plant nutrients. However plant growth is chiefly limited by the excessive drainage of these soils. The Whakaki soils, in contrast, are poorly drained, having high ground-water tables. They are strongly gleyed and have abundant mottles. Te Hapara soils have better soil development and a better supply of plant nutrients. There are two soil types within the series. Drainage of the low dunes or ridges (Te Hapara sandy loam) is rapid, although they are not as excessively drained as the dunes of the Opoutama series. The lower flatter areas (Te Hapara mottled sandy loam) are poorly drained with ground-water levels near the surface.

Topography

The topography consists of a series of low ridges and hummocks, usually with slopes less than 15°, and occasionally interspersed with narrow sand plains. Foredunes extend inland up to 0.5 kms, although in many places they are considerably narrower. Further inland the dunes are progressively more stable and less steep. At Gisborne these ridges are closely spaced and parallel to the coastline. They are commonly 1-2 m high and 20-40 m wide. Between Wairoa and Opoutama the dunes are less regularly spaced and sand plains are larger and more common. The dunes on the tombolo joining Mahia Peninsula to the mainland extend inland at right angles to the coastline, except near Opoutama where they are parallel to the coastline. Between Wairoa and Mahia Peninsula there are a number of ponds and small lakes impounded between the dunes.

Erosion

All areas within the suite have a potential for wind erosion. This varies from an extreme potential in the most exposed coastal localities (where the dunes are recent with very little soil development), to only a slight potential in the most sheltered inland localities (where dunes are older and with better soil development). However because of the generally well established cover of vegetation, present erosion (except on the foredunes) is only nil to moderate. Any exposure of bare sand can lead to wind erosion. On the younger dunes such 'blow outs' can soon increase in size, spreading sand onto surrounding vegetated areas. These areas are then difficult to revegetate and require the planting of sand binding species such as marram grass.

Vegetation

In this suite vegetation consists mainly of sand dune associations and pasture. The sand dune associations are found in the areas nearest the coast where there is little soil development, while the pasture is found further inland where the soils are better developed. Sand dune associations occupy 78% of the suite, 48% of which has a minor pasture component. Pasture occupies 20% of the suite, while 2% is in exotic forest. On the most stable inland sites at Gisborne maize is sometimes grown, and a small area of grapes has recently been planted.

The sand dune associations include the following: lupin, marram grass, fennel, blackberry, spinifex, pingao, and herbaceous weeds, with rushes and flax in poorly drained depressions.

Land Use and Land Management

Sheep and cattle grazing is the major land use within this suite, although much of the suite is undeveloped and serves an erosion control function. There is scope for further development of the more stable areas (class VI) but care must be taken in the conversion of the present vegetation to pasture or forest to ensure wind erosion is not initiated. More unstable areas (class VII) nearer the coast are at present mostly undeveloped and as such have a protective function. Attempts to develop these areas to pasture could endanger the more productive areas by movement of sand inland. Erosion control forestry would be the most effective conservation land use of these areas. The foredune areas should be managed for protection, either by maintaining the present vegetation in a suitable condition or by protection forestry. Actively eroding areas should be planted with sand binding species such as marram and spinifex. On the more sheltered, flat, inland sites at Gisborne, where there is adequate soil development, there is a potential for increased horticulture. In such cases irrigation would be necessary. Some of the larger wet sand plains would also be suitable for horticultural crops with adequate drainage. Care should be taken with cultivation to prevent deterioration in soil structure.

Shelter is an essential requirement for safe and intensive use of sand country. Windbreaks are necessary throughout the suite to reduce wind erosion and the effect that wind and salt spray have on the growth of pasture, trees and crops. Grazing management is an important factor in the control of erosion. Fences should separate the more unstable areas to allow for reduced grazing pressure on these areas. Fences and tracks should also be sited to avoid stock concentrations and so prevent erosion resulting from opening up of the vegetative cover.

Land Use Capabilty Units

The suite comprises 5 LUC units: VHIel, VIIel3, VIel3, IVsl and IIIs5. Apart from VHIel the suite is well suited to forestry, with site indices which range from medium to high. The potential stock carrying cpacity range however is very low to medium. Figure 31 illustrates the relationship between the LUC units.

LUC unit VIHel (450 ha)—Figure 32

This unit is mapped on the coastal foredunes, a narrow unstable belt of recent windblown sand. These dunes are the most exposed and have the least soil development. This together with the rolling nature of the dunes gives them the potential for extreme wind erosion. At present, wind erosion is very severe with large areas of bare sand, vegetation being restricted to sand dune associations such as marram grass. Soils are those of the Opoutama series, although in fact very little soil development has taken place. Within the foredune zone the area of sand plains (Whakaki series) is very restricted.

Due to the erosion hazard this unit should be managed for protection purposes, not only of the dunes themselves but also to protect more productive areas inland. Areas of bare and eroding sand need to be stabilised by planting suitable species such as marram grass, spinifex, or lupin. Areas presently stable need careful management to minimise surface disturbance since once this has occurred the underlying sand is highly susceptible to wind erosion.

The scale of mapping has not always allowed an area of VHIel to be mapped immediately inland from the beach, however in all cases such an area will occur.

LUC unit VIIel3 (1,050 ha)—Figure 32

Vile 13 is mapped immediately inland from VHIel where the dunes are in a more stable condition. Slopes are less than 15° and have a more established, extensive vegetation cover. Despite this there is still a potential for very severe to extreme wind erosion, although present erosion is only moderate.

On the tombolo between Opoutama and Mahia Beach wind erosion was so severe during the 1940s that extensive planting was undertaken to stabilise the dunes. An area of approximately 100 ha near Opoutama was planted in pines, while a larger adjacent area was planted in marram grass. Today erosion in both areas has been dramatically reduced, although occasional blow outs still occur in the area planted with marram grass. The area of pines clearly illustrates the effect of wind and salt spray on tree growth. The first rows of trees, which are only 300 m back from the beach are stunted, wind pruned and affected by salt burn, while those further inland are progressively taller and of better form, having been protected by the trees nearer the coast.

There is still a need to prevent surface disturbance and improve the vegetation cover as soils are shallow. However the unit is capable of productive use if conservation measures are adopted. Safest use is erosion control forestry, managed to protect and stabilise sand and still yield a tree crop. Site index for *P. radiata* is 25-28 m. The potential stock carrying capacity is only 3 su/ha, pasture growth being limited by long periods of soil moisture deficiency. Care needs to be taken to prevent blow outs initiated by stock concentrations.

LUC unit VIel3 (2,250 ha)—Figure 33

In this LUC unit the dunes are slightly less steep than those in Vile 13. They are undulating to rolling (Opoutama soils) with a larger percentage of sand plains (Whakaki soils) in the complex. The sand is more consolidated and topsoils and subsoils are more strongly developed. The unit occurs inland from Vile 13 or in more sheltered locations. Erosion is still a problem with slight wind erosion at present and a moderate potential.

Vegetation comprises lupins and other sand dune associations together with low producing pasture. The unit is used for grazing and is suited to either production forestry or improved grazing having a site index for *P. radiata* of 25-28 m. and a potential stock carrying capacity of 12 su/ha. The site index for Vie 13 is lower than that for Vile 13 because of the larger area of wet sand plains in Vie 13.

Care still needs to be taken to reduce the risk of wind erosion and wind breaks would be of value. Erosion control forestry on the neighbouring Vile 13 would help provide shelter for VIel3. The sand plains require drainage to maintain high producing pasture and improve tree growth. The dunes are subject to summer droughts which severely reduce pasture growth.

LUC unit IVsl (250 ha)—Figure 34

A small area of IVsl occurs on the outskirts of Gisborne, and also near Table Cape on Mahia Peninsula. These are flat or undulating low sand dunes and well drained sand plains which are stable under a grass cover and have only a slight wind erosion potential when cultivated. In this unit therefore erosion is no longer the major limitation to use, the droughtiness of the soils together with poor soil structure and low nutrient levels are more important. The soils belong to the Opoutama series and at present support both low and high producing pasture.

Any cropping should be preceded by shelterbelt planting. Because the soils have a weakly developed structure and a poor moisture holding capacity the unit is best suited to deeply rooted permanent crops. Irrigation would be required in such areas. Site index for *P. radiata* is 25-30 metres and the potential stock carrying capacity is 10 su/ha.

LUC unit IIIs5 (600 ha)—Figure 35

This unit also occurs on the outskirts of Gisborne and extends inland from IVsl. It consists of low undulating ridges and flat sand plains which are stable and have been mantled by a thin layer of rhyolitic pumice (up to 28 cm thick). The ridges are excessively drained and the soil type is Te Hapara sandy loam. The low lying areas are poorly drained with water tables 1-1.5 m from the surface in winter. Here the soil type is Te Hapara mottled sandy loam. Again, although slight wind erosion may occur when this unit is cultivated, the major limitations to use are excessively drained soils together with low nutrient levels. Because these dunes are older than those of IVsl and have also been mantled by a layer of pumice the resulting soil is deeper and more strongly developed. The unit is presently used for grazing (with a potential stock carrying capacity of 12 su/ha) pig and poultry farming, and maize cropping. There are also small areas of orchards and vineyards. With shelter and irrigation there is a potential for an increase in the area and range of crops. Site index for *P. radiata* is 25-30 m.

	Vlllel	Vlle13	Vle13	IVs	llls5
Slope	C+B B+C	C+B B+C	B+C	B	A A+B
Erosion Potential	Extreme	Very severe to extreme	Moderate	Slight (when cultivated)	Slight (when cultivated)
Potential Land Use	Protection Forestry	Erosion Control Forestry	Production Forestry Grazing	Grazing Cropping	Grazing Horticulture
Potential Stock Carrying Capacity (su/ha)	Unsuitable	3	1 2	10	1 2
Site Index (m)	Unsuitable	25-28	25-28	25-30	25-30

Figure 31: Relationship between LUC units on sand dunes.

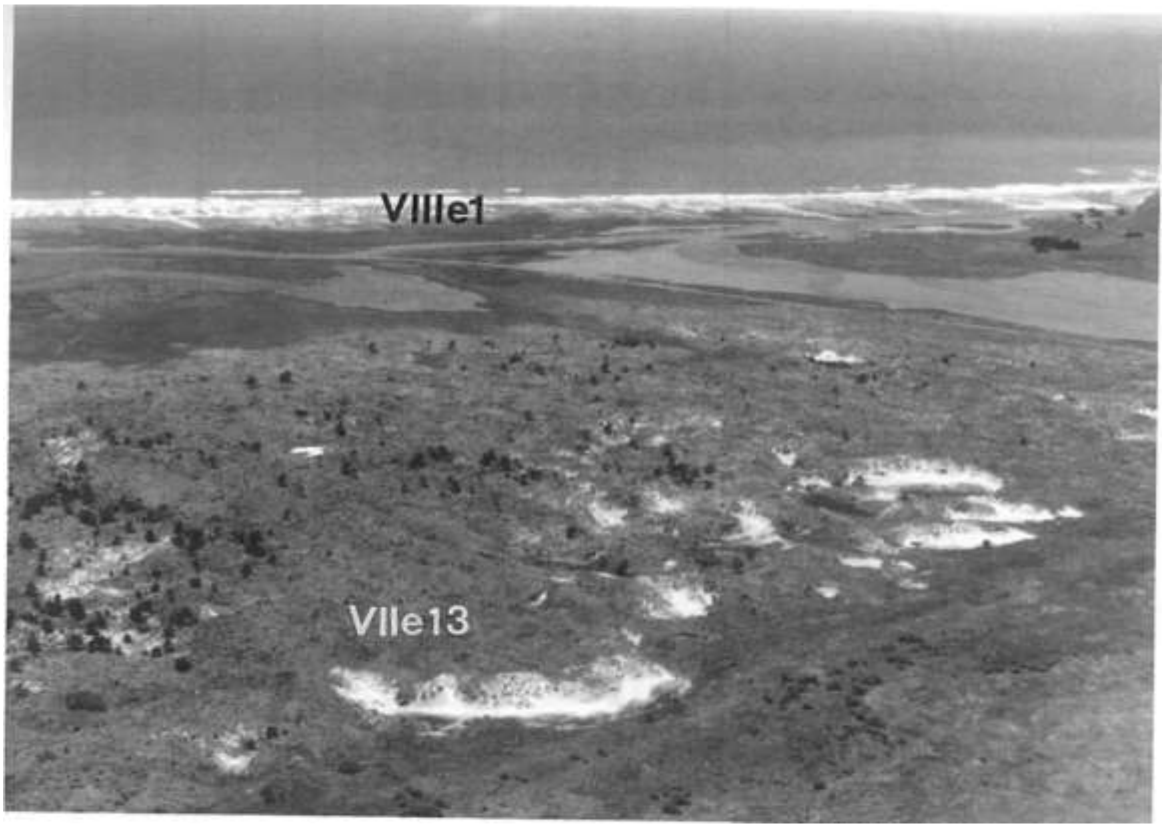


Figure 32: VIIel3. Between Opoutama and Mahia Beach. Nl 16/245890, looking south-east. Vlllel in background. Photo: N A Trustrum

Figure 33: VIel3. Gisborne. N98/362360, looking west.

Figure 34: IVs1. Awapuni Road, Gisborne. N98/365365, looking north-east.

Figure 35: IIIs5. Inland margin of sand country. Note presence of rushes on alluvial IIIw1 in background (LUC suite 1). Hansen Road Gisborne. N98/363413, looking north-west.

LUC SUITE 5: LOW ANGLE UNSTABLE MUDSTONE TERRAIN

Scattered throughout the hill country inland from Gisborne and Wairoa are isolated pockets of deep-seated erosion. These areas are usually strongly rolling to moderately steep and occur on crush zones, faults or are related to structural features. In these cases the rock type is normally jointed mudstone. Such deep-seated erosion also occurs where the rock type is estuarine sediments or bentonitic mudstone. Because of the subdued topography many areas are mantled by a layer of tephra which increases in depth towards the west.

Four LUC units have been mapped on this terrain, all with erosion as the major limitation to use (Figure 36). One unit occurs on unconsolidated estuarine sediments, while the other three all occur on mudstone and are defined on the basis of erosion potential. The potential for erosion is influenced by factors such as the composition of the mudstone, the intensity of faulting and crushing, the degree of undercutting by streams and the nature of surrounding geological structures. The suite totals 26,880 ha and occupies 2.3% of the Region.

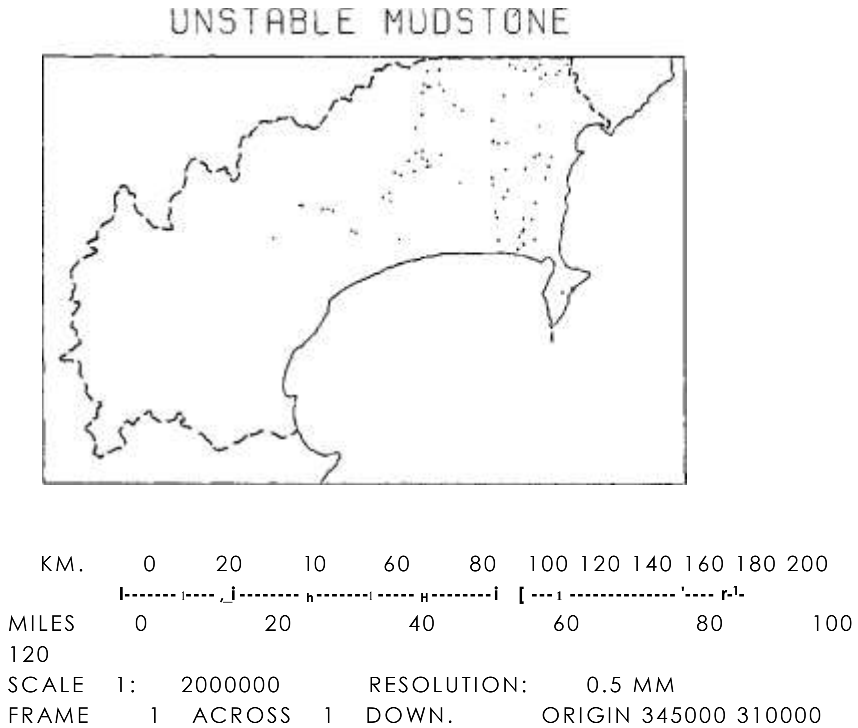


Figure 36: Location of LUC suite on low angle, unstable mudstone terrain.

Climate

Because LUC units in this suite are widely scattered from Mahia Peninsula to the headwaters of the Hangaroa River, and from sea level to an altitude of 760 m, there is a correspondingly wide range in climatic conditions. The climate varies from warm and moist towards the coast to cool and wet in inland upland areas where frosts are common in winter and snowfalls may occur. Rainfall varies from 1000 mm p.a. near the Gisborne Plains to 2,500 mm p.a. in the headwaters of the Mangapoike River. However the ability of the parent material to store water and the presence of springs means that erosion potential is largely independant of annual rainfall. Droughts are common near the Gisborne Plains and in areas nearer the coast.

Rock Type

The rock types in this suite consist of jointed mudstone, bentonitic mudstone and unconsolidated estuarine sediments. All are Tertiary in age.

Jointed mudstone is the major rock type. As in LUC suite 6 the mudstone exhibits a jointing pattern on weathering, only here, as a result of crushing, the jointing is more open and the mudstone more incohesive. This material has been referred to as loose-jointed mudstone by O'Byrne (1967). There is also an increase in swelling clays, such as montmorillonite, due to increased weathering rates caused by crushing.

Small areas of bentonitic mudstone occur, usually associated with crush zones. This material is older than the jointed mudstones, being generally Eocene in age. Although moderately hard when dry it becomes very soft when water-saturated. The ability to absorb water is greater than for the jointed mudstones and the material may eventually develop earthflows on slopes as low as 8°(Hamilton and Kelman 1952).

Estuarine sediments (O'Byrne 1967) are Pliocene and younger in age. They consist of successive layers of unconsolidated clays, sands and tephra.

A mantle of tephra of varying thickness overlies these rock types. It increases in depth towards the west and consists of some or all of the following; Taupo Pumice, Waimahia Formation and older tephras such as Rotoma Ash and Waiohau Ash.

Soils

The soils in this suite have been mapped from two soil surveys. North of Tiniroto soils are those of the General Survey (New Zealand Soil Bureau 1954) (55% of the suite), while south of Tiniroto the soils have been mapped using the Wairoa County Survey (Rijkse unpublished) (45% of the suite). The soils are mainly hill soils although small areas of easy rolling soils and steepland soils occur. Erosion is so deep-seated that the nature of the soil has no significant effect on land use capability. For this reason soils within the suite may be yellow-brown earths, composite yellow-brown pumice soils on yellow-brown loams, yellow-brown pumice soils or podzolised yellow-brown pumice soils.

Topography

Topography in this suite is very distinctive. The hills are of generally low relief and slopes are often long and broken by large deep-seated earthflows and slumps and at times by long linear gullies. These deep-seated movements are often on lower slopes or in basin areas and are separated from one another by stable ridges and spurs. At times stable 'islands' remain within the earthflows. Where earthflows and slumps occur the surface is broken and hummocky with areas of ponding, especially near the head of the movement. Slopes vary from strongly rolling to moderately steep. This subdued and disrupted terrain contrasts strongly with the surrounding 'hills'.

Erosion

The potential for erosion varies from moderate to extreme and depends largely upon lithological characteristics. The main erosion types are deep-seated earthflow and slump. These may be many metres deep and are often drained by gullies which have developed within them. The toes of these movements are often undercut by streams and rivers, adding to slope instability. Areas of deep-seated erosion usually involve relatively large areas, a single movement perhaps covering a whole hillside. Minor soil slip erosion may also occur on sites unaffected by deep-seated erosion.

The deep, wide joints within the mudstone allow water to enter to a considerable depth. During dry periods the surface layers crack, allowing even greater penetration. Ponding of water, caused by ground movement interrupting surface drainage, together with springs, further promote the movement of earthflows and slumps. Often such movements develop their own drainage in the form of a gully, however in the process the gully adds further to surface disruption and often removes material into watercourses at a greater rate than the earthflow or slump itself.

Areas mapped within the suite may be actively eroding or in some cases practically stable after a previous period of erosion. However even these partially stable areas usually have a potential for further erosion, and in fact in some cases old stabilised movements have been reactivated. One such example occurs on the Mangaone Road north of Nuhaka (Figure 44). Here is an area which has 'historically' experienced deep-seated erosion, followed by a period of relative stability. During the 1950s a new cycle of erosion began. Movement has been so severe and deep-seated that a stand of remnant forest has been destroyed and the county road has had to be realigned above the present head of the movement. Rates of movement have been assessed from measurements taken from aerial photographs of various ages. These show that in the 13 years between 1962 and 1975 features such as boulders and trees have moved by up to 60 m (D Hicks, pers. comm.). At Waerengaokuri near Gisborne movements of 2.1 m in 35 days and 4.5 m in 160 days have been recorded on a bentonitic earthflow (Bishop 1968).

Vegetation

Because of the easy contour and high fertility the majority of this suite is in high producing pasture, with only small areas of low producing pasture, scrub or fern. A small area near the Urewera National Park is in indigenous forest. The poorly drained nature of most areas means that rushes are common, and sedges may also be present where ponding occurs.

Although erosion is a dominant feature, conservation planting of poplars and willows is not common. In several areas *Pinus radiata* has been block planted for erosion control.

Land Use and Land Management

The land within this suite is intensively farmed. Production is generally above average for hill country. The soils that have developed on this subdued topography are moderately deep and drainage is such that during droughts these areas retain moisture longer than other hill country. Limitations to production centre almost entirely around the erosion hazard. The effects of erosion include loss of land suitable for production, reductions in pasture or tree growth caused by waterlogging and movement, difficulty of management (due to poor access, loss of fences, tracks, stock or trees, and difficulty of subdivision).

Because of the deep-seated nature of the erosion the soil conservation measures required on this suite are more radical than the normal open planting of poplars and willows. Where the erosion is particularly severe changes in land use may be necessary. In most cases the area affected by deep-seated erosion is large, and may involve a number of properties. It is important to treat the whole of this unstable area in a co-ordinated fashion and not just part of it. Co-operation between affected properties is important.

Removal of water is vital in the control of earthflows and slumps. Trees play an important role in de-watering through uptake of water by roots and subsequent transpiration. However in many cases mechanical means of de-watering are also necessary. These include spring tapping, surface smoothing and graded banks. Where movements are undercut at the toe by streams it is necessary to provide protection either by stream diversion or tree planting. Gully control requires debris dams and willow planting. Fences and tracks need to be sited on stable ground, and stock ponds should be carefully placed to prevent infiltration of water. Earthflows are particularly susceptible to surface pugging, which increases infiltration rates. To prevent this cattle should not be wintered on such areas. Trees may be open planted or block planted in some cases, but where erosion is particularly active and deep-seated, erosion control forestry is necessary.

Land Use Capability Units

There are 4 LUC units in this suite. VIe9 is mapped on estuarine sediments, while Vie 10, VIIe6 and VllelO are mapped on mudstone. In all cases erosion is the major limitation. Unlike many other suites, changes in land use capability in this suite are not related to slope, climate or soils. In the case of VIelO, VIIe6 and VllelO land use capability is defined solely on the basis of erosion potential. The effect of erosion on productivity in these 3 units can be seen in Table 21. The decreases in productivity are almost entirely the result of increases in erosion severity.

Table 21: Relationship between LUC units, productivity and erosion on low angle unstable mudstone terrain

LUC Unit	Erosion Potential	Potential Stock Carrying Capacity (su/ha)	Site Index for *Pinus radiata* (m)
Vie 10	Moderate	15	30-33
VIIe6	Severe	11	28-32
VllelO	Very severe to extreme	7	27-29

In other Regions there are LUC units for bentonitic and for non-bentonitic mudstones. In the North Island Correlation of Regional Land Use Capability Units (Page 1985) Vie 10 has been subdivided on this basis and correlated with the appropriate LUC units from other Regions.

LUC **unit VIe9** (1**,600 ha)—**Figure 37

This LUC unit is restricted to an area just south of Te Karaka near the head of the Gisborne Plains. It is mapped on low hills which, unlike other LUC units in the suite, are formed on estuarine sediments. These sediments are unconsolidated and are prone to moderate to severe earthflow and slump erosion. Some soil slip and gully erosion may also occur. The topography is strongly rolling and rounded in appearance with a shallow mantle of tephra on the ridges. Soils include Gisborne sandy loam and Otamauri sandy loam, hill soil. Wetness is a problem despite a rainfall of only 1000 mm p.a. The broken nature of the surface together with poor internal drainage are limitations to pasture production and contribute to the deep-seated earthflow and slump erosion.

Recommended soil conservation measures are open planting of slopes with poplars, pair planting of gullies with willows together with debris dams and dewatering and smoothing of earthflows to reduce infiltration rates.

The unit is almost entirely in pasture with a high incidence of rushes. The potential stock carrying capacity figure is 13 su/ha and the site index for *P. radiata* is 30-34 m.

LUC **unit VIelO (9,380h ha)—**Figure 38

Vie 10 is mapped on areas of mudstone associated with crush zones or on bentonitic mudstone, where erosion potential is moderate. Erosion forms are deep-seated earthflow, slump and gully and minor soil slip. Slopes are strongly rolling to moderately steep and often long. Many areas of Vie 10 are the sites of historic earth movements, in some cases thousands of years old. These areas have subsequently been mantled by a series of tephras. The presence therefore of an undisturbed sequence of tephras indicate that the area has since been relatively stable. In some cases such areas have recently been reactivated. The soils are therefore often yellow-brown pumice soils, e.g., Ruakituri or Tuai series; or composite yellow-brown pumice soils on yellow-brown loams, e.g., Mahia series. In areas where tephra is absent soils are yellow-brown earths, e.g., Mangatea series. On this LUC unit soil conservation measures compatible with pastoral farming can minimise erosion. The potential stock carrying capacity figure is 15 su/ha and the site index for *P. radiata* is 30-33 m.

LUC **unit VIIe6 (14,070 ha)—**Figure 39

VIIe6 is mapped where the potential for erosion is severe. This is the result of increased crushing of the mudstone or active undercutting by streams. Here the strongly rolling nature of the surface can be deceptive, giving the appearance of stability. Yet despite the severe potential for erosion, with more intensive soil conservation measures than those used in VIelO, these areas can still be used for pastoral farming. De-watering to reduce infiltration is especially important. Methods include surface treatments such as smoothing, levelling, graded banks and diversion channels. Spring tapping also helps remove water from within the earthflow. Block planting of critical areas is also necessary. Any forestry on this LUC unit should have an erosion control function. The increase in erosion has reduced the potential stock carrying capacity to 11 su/ha and the site index for *P. radiata* to 28-32 m.

LUC unit **VllelO** (2,830 **ha)—**Figure 40

Small areas occur where more intensive crushing, steeper slopes, and/or more active stream undercutting, has led to a very severe to extreme potential for erosion. In these cases experience has shown that pastoral farming with traditional soil conservation measures is not a suitable long-term use. These areas are best used for erosion control forestry, whereby the forest is managed both for production and to mitigate erosion. The site index for *P. radiata* is 27-29 m while the potential stock carrying capacity is only 7 su/ha.

Two examples of VllelO occur at Waerengaokuri, and on Mangaone Road near Nuhaka. At Waerengaokuri the erosion is so serious that the whole area has been planted up with trees and is administered as a soil conservation reserve by the East Cape Catchment Board. Headward gully erosion of the Te Aroha stream threatens an area of fertile flats at the head of the catchment, and debris dams and drop structures have been installed in an attempt to prevent further erosion. At Mangaone Road an extensive area of hillside, which has been unstable 'historically', has recently been reactivated. It consists of a series of slumps, earth-flows and gullies which by progressive headward erosion are extending up slope towards the head of the catchment. Primarily because of the threat to the already realigned county road part of this movement has recently been planted in pines.

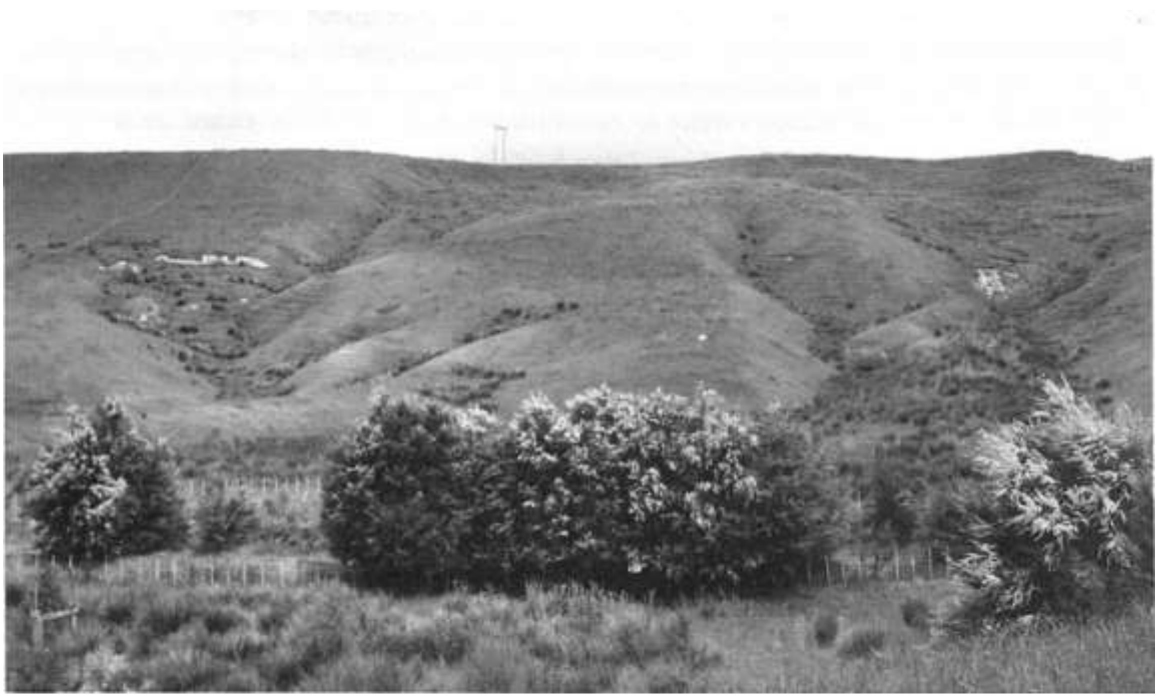


Figure 37: VIe9. Dymocks Road, south of Te Karaka. N98/273576, looking south.

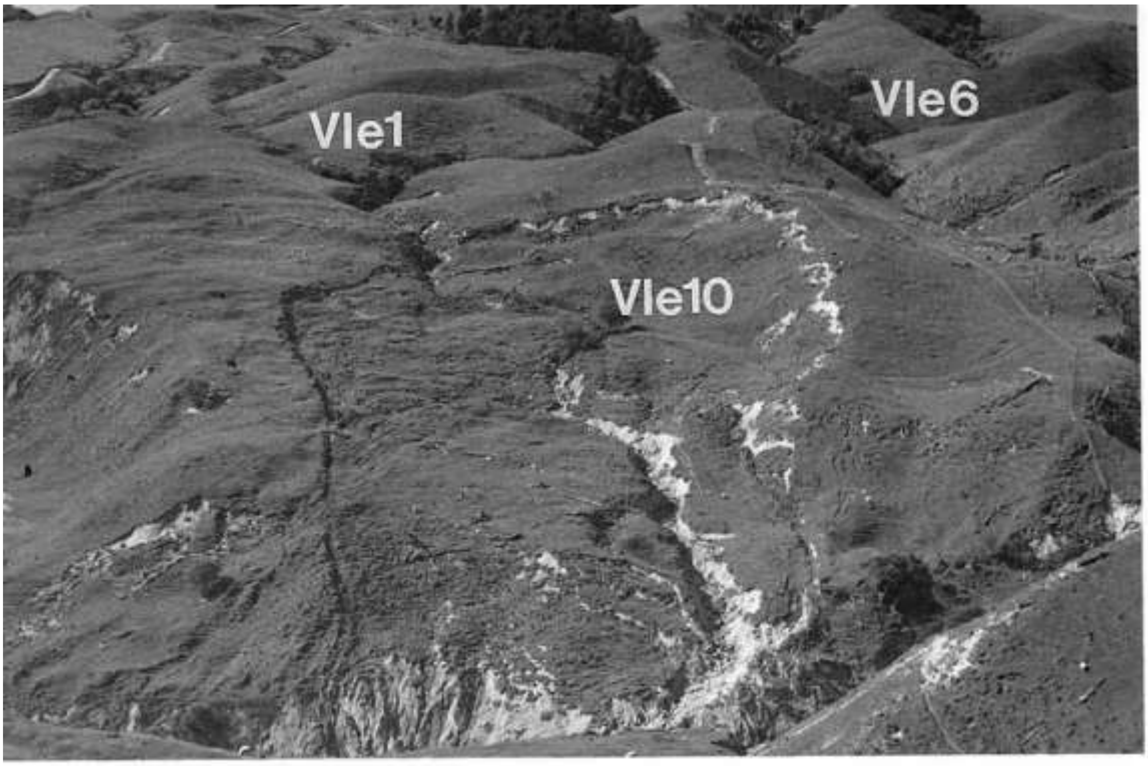


Figure 38: VIe10. Waireka Road, west of Putere. N105/357051, looking east. Stable hills are VIe1 and VIe6 (LUC suite 11). Photo: G R Harmsworth

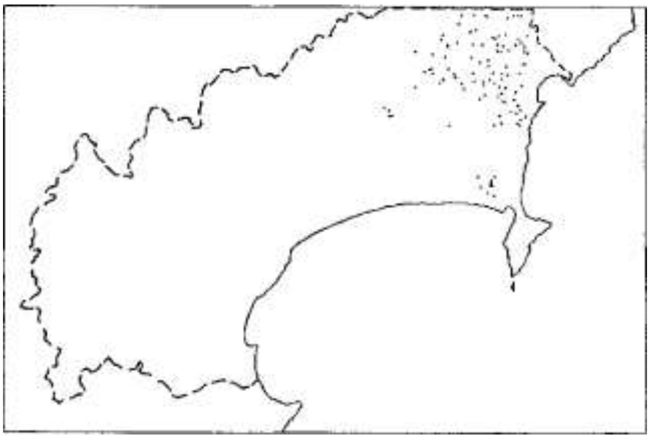
Figure 39: VIIe6. Totangi Road, north of Ngatapa. N97/172545, looking north.

Figure 40: VllelO. Mangaone Road, north of Nuhaka. Nl 16/116985, looking west. Photo: N A Trustrum

LUC SUITE 6: JOINTED MUDSTONE HILL COUNTRY

In the north-east of the Region there are 52,670 ha of fertile hill country which is subject to soil slip and shallow earthflow erosion. Principal areas are south and west of the Gisborne Plains, near Morere, and throughout the Hangaroa-Rere district (Figure 41). These hills are formed from jointed mudstone and it is the characteristics of this rock type which lead to the shallow earthflow erosion. This hill country forms a suite consisting of two LUC units, VIe3 and Vllel, which are normally found together in the landscape. The suite occupies 4.6% of the Region. As with a number of other hill country suites the LUC units are defined on the basis of a combination of erosion potential and slope.

JOINTED MUDSTONE



KM. 0 20 10 BO 80 100 120 140 160 180 200

MILES 0 20 40 60 80 100 120

SCALE 1: 2000000 RESOLUTION: 0.5 MM

FRAME 1 ACROSS 1 DOWN. ORIGIN 345000 310000

Figure 41: Location of LUC suite on jointed mudstone hill country.

Climate

As with most of the hill country in the Northern Hawke's Bay Region rainfall has both a high monthly and annual variability. Droughts are common as are high intensity rainstorms. Rainfall has a winter maximum and a spring-summer minimum. Annual rainfall is 1000 mm near the Gisborne Plains, 1600 mm further inland and reaches 1800 mm at Morere.

The suite occurs along the western edge of the Gisborne Plains and along inland valleys. Such locations are relatively sheltered, experiencing few strong winds. The main wind direction is from the north-west, especially near the Gisborne Plains, although further inland this varies somewhat with local topography. Summers are very warm and winters are mild, with approximately 40 ground frosts per year.

Rock Type

In this suite the rock type consists of Tertiary mudstone which exhibits a close-spaced jointing pattern on weathering. Bedding is normally absent and in the NZLRI rock type classification this material has been included in the jointed mudstone category (Crippen and Eyles 1985). This material is extensive throughout the Gisborne-East Cape district and has been referred to as close-jointed mudstone by O'Byrne (1967). It is highly calcareous and is composed of dominantly clay size particles. Montmorillonite, the major clay mineral, exhibits swelling and shrinking properties. This ability is an important factor in the movement of earthflows.

Near Gisborne some rhyolitic tephra is present on ridges and stable areas not affected by erosion. However the tephra is shallow and has little influence on land use. Towards the west, in the Hangaroa-Rere district, the depth of tephra increases. Where it is still sufficiently shallow for the properties of the underlying rock to be expressed these areas are mapped within the jointed mudstone suite. However beyond Wharekopae the depth of tephra is sufficient to mask the properties of the mudstone and shallow earthflows are no longer present. Such areas are mapped within LUC suite **11.**

Soils

The soils are mainly yellow-brown earths, although towards the east, bordering the Gisborne Plain soils are intergrades between yellow-grey earths and yellow-brown earths and composite yellow-brown pumice soils on yellow-grey earths. In the west yellow-brown pumice soils are common especially on easier slopes. Apart from at Morere soils are those from the General Survey (New Zealand Soil Bureau 1954). At Morere the soils have been mapped using the Wairoa County Survey (Rijkse unpublished).

The soils have developed in large part from the jointed mudstone and are fertile and moderately well drained. Where the tephra is deeper soils are less fertile, well drained and with a less well developed structure.

Topography

The hills are of variable shape with numerous spurs and narrow ridges. They have v-shaped valleys except where they border alluvial terraces or plains. Here there is a build up of colluvium at the base of the hills. Slopes are moderately steep to steep and are generally not long. The variable shape of the hills is enhanced by the broken, irregular surfaces formed by the soil slips, earthflows and gullies that are a feature of this suite.

Erosion

There is a potential for moderate to severe erosion, which is related to slope angle, the nature of the jointing in the mudstone, and the presence of minor faults and crush zones. The major erosion types are soil slip and shallow earthflow, and less commonly gully. Sheet erosion also occurs, especially in drier areas. Localised slump erosion is usually related to structural features, faults or crush zones.

Soil slip erosion is characteristic of this suite, as it is of all Tertiary hill country throughout the Region, and occurs in response to rainstorms or sometimes earthquakes. Shallow earthflows are however characteristic of this suite only and are related to the jointed nature of the mudstone and the presence of swelling clays. This jointing facilitates penetration of water into the rock, and subsequent swelling of clays such as montmorillonite. These attributes coupled with high pore water pressures, facilitate earthflow movement. These earthflows are shallow in nature, usually less than **1** metre deep, in contrast to deep-seated movements where the rock is more loosely jointed, jointing is deeper and the proportion of swelling clays is higher. Shallow earthflows occur on relatively steep slopes (>20°) and are normally localised movements, much narrower than they are long. Unlike soil slips they move slowly and intermittently.

Another factor which promotes earthflow erosion is the variability of the rainfall. During drought periods the surface layers dry out and crack, the clay component of the mudstone shrinks causing the joints to widen, and when rain occurs water is easily able to penetrate into the mudstone via these cracks causing the clays to swell. This wetting-drying shrinking-swelling cycle causes mechanical weathering of the rock. This ability for water to be taken into the mudstone is an important factor in the formation of earthflows. Observations suggest that earthflow movement is increased in winters following very dry summers.

Gully erosion, although not severe, is common throughout the suite. The gullies are associated with drainage channels and are linear in form and not very deep.

Vegetation

Pasture is the dominant vegetation. At the time of mapping 70% of the suite consisted of pasture, with some manuka either scattered or in small blocks. The remaining 30% consisted of pasture without a significant scrub component. The pasture contains mainly high producing species, especially near the Gisborne Plains. Scattered rushes occur on the poorly drained lower slopes. Localised plantings of poplars and willows have been made for erosion control purposes.

Land Use and Land Management

Land within this suite is used entirely for sheep and cattle farming. Although the land has been developed, scrub reversion does occur. However a far greater problem is that of erosion. Although erosion may be severe, and involve a number of different erosion processes, soil conservation measures compatible with pastoral farming have been developed. These measures, although not capable of preventing erosion entirely, do provide a degree of control.

Slopes subject to soil slip and shallow earthflow are open planted with poplars. Gullies and stream courses are pair planted with willows. Where gullies are actively eroding, debris dams are constructed to trap sediment and prevent further gullying. Localised erosion which will not respond to these techniques is block planted with poplars or pines. Where earthflows are undercut at their base by streams, river bank planting is necessary.

Earthflows become very wet in winter and their surfaces are susceptible to pugging, which increases infiltration of water. To prevent this cattle should not be wintered on such areas. Because of their slow and intermittent movement earthflows cause continual disruption of tracks and fences and these need to be sited where ground is stable.

Land Use Capabilty Units

In this suite erosion is the major constraint upon land use, although droughts have a limiting effect on production. Being formed from jointed mudstone this is among the most fertile hill country in the Region. The two LUC units, VIe3 and Vllel are associated together in the landscape, with Vllel occurring on the steeper areas where erosion potential is greater.

In the Southern Hawke's Bay-Waifarapa Region and the Taranaki-Manawatu Region the equivalent LUC units have been subdivided on the basis of rainfall into LUC units where rainfall is less than 1200 mm p.a. and LUC units where rainfall is greater than 1200 mm p.a. Areas where rainfall is less than 1200 mm p.a. are subject to more severe droughts than areas above 1200 mm p.a., with a consequent reduction in pasture growth. These areas also have a potential for more sheet erosion because the drier conditions result in a less complete pasture cover. In the North Island Correlation of Regional Land Use Capability Units (Page 1985), VIe3 and Vllel from the Northern Hawke's Bay Region have been correlated to the appropriate LUC units from these other Regions. On this basis 14,330 ha of VIe3 has a rainfall greater than 1200 mm p.a. and 16,810 ha has a rainfall less than 1200 mm p.a. Likewise 16,180 ha of Vllel has a rainfall greater than 1200 mm p.a. and 5,280 ha has a rainfall less than 1200 mm p.a.

LUC unit VIe3 (31,140 ha)—Figures 42, 43

VIe3 is mapped where slopes are moderately steep to steep. Here erosion potential is moderate, and soil slips tend to occur on the steeper slopes and earthflows on the lower slopes. Hill slope morphology tends to suggest a fairly rapid rate of erosion, however because of the fertile nature of the parent material scars heal rapidly.

Typical soils include Pouawa sandy loam hill soil and Pakarae sandy loam hill soil and, in the west where a shallow mantle of rhyolitic tephra is present, Taupo sandy silt hill soil and Gisborne sandy loam hill soil. On steeper slopes a common soil is Turakina silt loam.

Soil conservation measures are particularly successful on this LUC unit and with good management there is a potential for a carrying capacity of 16 su/ha which is high for hill country. The site index for *P. radiata* is also high at 30-33 m.

LUC unit **Vllel** (21,460 **ha)—**Figure 44

On steep to very steep slopes the erosion potential is severe. Slopes are longer and soils shallower than in VIe3. There is an increase in the incidence of soil slips and earthflows and soil slips tend to occur on steeper sites and so heal more slowly. Potential productivity, although still relatively high, is lower than for VIe3. Areas with this degree of limitation are mapped as Vllel.

Typical soils are Mahoenui silt loam, Turakina silt loam and Waitaha sandy loam. These are all steepland soils, although because of the variability of the topography some hill soils also occur.

Because of the erosion potential of Vllel careful management is required. The same soil conservation measures are necessary as used for VIe3, but on a more intensive scale. Block planting or retirement of small areas is sometimes necessary, and low density agroforestry is recommended. Potential stock carrying capacity is 15 su/ha, while site index for *P. radiata* is 28-32 m. Any forests established on Vllel should have an erosion control function.

At Young Nicks Head the jointed mudstone hills terminate in coastal cliffs, which are mapped as VIIIe3 (70 ha). The cliffs are near vertical and are almost entirely bare rock, with only a little tauhinu growing on favourable sites.

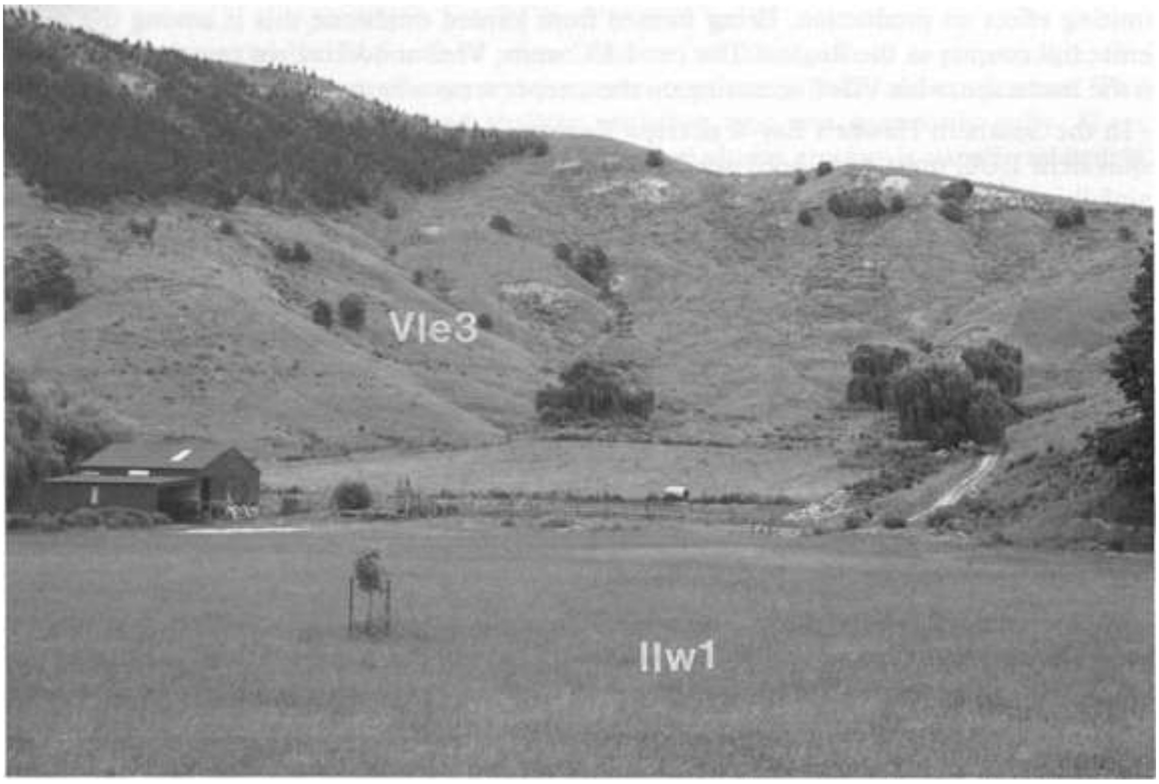


Figure 42: VIe3. Ngatapa. N97/189455, looking west. IIwl flats in foreground (LUC suite 1).

Figure **43:** VIe3. Effects of March 1985 Ngatapa storm. State highway 36 from Gentle Annie Hill. N97/226374, looking south-east. Debris covering IIwl flats in foreground (LUC suite 1). Photo: G O Eyles

Figure **44:** Vllel. Effects of March 1985 Ngatapa storm. State highway 36 from Gentle Annie Hill. N97/222370, looking south. Photo: G O Eyles

LUC SUITE 7: BANDED MUDSTONE HILL COUNTRY

This suite of 52,660 ha is scattered throughout the northern part of the Region, particularly in the Hangaroa district, Ruakituri Valley, Mangaaruhe Valley, between Tukemokihi and Whakaki and on Mahia Peninsula (Figure 45). It consists of hills and gorges where the rock type is banded mudstone. Land use is almost entirely pastoral farming, although manuka and mixed indigenous scrub are common. Land use capability in this suite is assessed on the basis of erosion potential and slope. Erosion types are soil slip, sheet and gully.

The suite contains 3 LUC units, occupying 4.6% of the Region. They are found in association with a wide range of other LUC units from a number of other hill country suites.

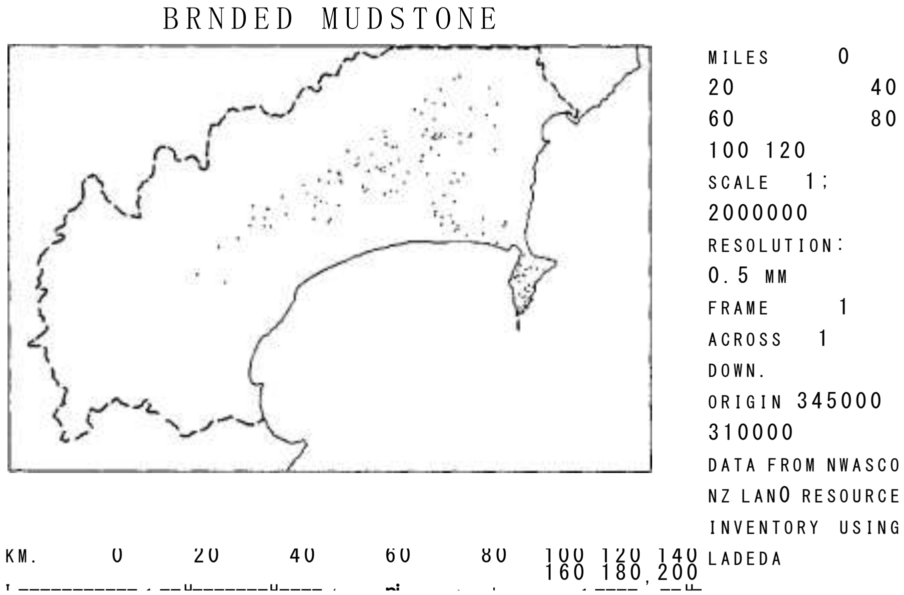


Figure **45:** Location of LUC suite on banded mudstone hill country.

Climate

The climate is typical for east coast hill country. The annual rainfall is between 1200-2000 mm, with lower totals occurring nearer the coast. Rainfall has a winter maximum and summer minimum and although droughts do occur they are not usually severe. Occasional high intensity rainstorms may occur in any season. The suite generally occurs in sheltered inland valleys and wind direction depends on local topography. Summers are warm and winters mild.

The area on Mahia Peninsula, although similar in most other respects, has a somewhat different climate to other areas within the suite. Here the climate has a strong coastal influence. The peninsula is exposed and is affected by salt-laden winds, and although the annual rainfall is between 1200-1600 mm droughts are more common. As a result productivity, especially for trees, is lower than for inland sheltered sites.

Rock Type

Banded mudstone consists of mudstone, usually jointed to some degree, interbedded with coarser and harder sandstone. The sandstone beds are of variable thickness and frequency, but always less dominant than the mudstone. Bedding is typically gently dipping and only occasionally is it moderately to steeply dipping. Also included in the suite are small areas of massive mudstone where the erosion properties are the same as those of banded mudstone. The rocks are Pliocene and Miocene in age.

A shallow mantle of rhyolitic tephra is present where slopes are less steep or stable, and the depth increases in the north-west of the suite.

Soils

The LUC units in this suite are scattered over a wide area and include a number of different soils belonging to several different soil groups. In areas inland from Wairoa soils are yellow-brown earths and related steepland soils or steepland soils related to yellow-brown pumice soils. On Mahia Peninsula soils are mainly steepland soils related to intergrades between yellow-grey earths and yellow-brown earths, or composite yellow-brown pumice soils on yellow-brown loams.

The soils have been mapped using the Wairoa County Survey (Rijkse unpublished) and include the following series: Mahoenui, Hangaroa, Pakarae, Taihape, Tutira and Waitaha. In the Hangaroa district Mahoenui, Hangaroa and Taihape soils are mapped from the General Survey (New Zealand Soil Bureau 1954).

The soils are generally of medium natural fertility, shallow and moderately well drained. In the case of soils developed on tephra, the tephra cover is shallow enough for characteristics of the underlying banded mudstone to be expressed.

Topography

The suite occurs on moderately steep to very steep hill country, and includes gorges and bluffs where slopes are over-steepened along actively downcutting rivers. Slopes are generally planar in profile, leading directly into streams. Very long slopes are characteristic of the steeper hill country and gorges, where bedding may be apparent through the shallow soils. In most areas the topography has a typical hill form. However in the Mangapoike Valley bedding of the mudstone is well developed and dips towards the west forming a series of scarp and dip slopes which are part of the Wairoa Syncline.

Erosion

The major erosion form is soil slip with minor sheet and gully erosion also present. Erosion severity is related to slope angle and degree of bedding of the mudstone. Where bedding is well developed slopes are relatively stable. As with other areas of hill country in the Wairoa district earthquakes, in addition to high intensity rainstorms, have been observed to initiate slipping.

Soil slips on moderately steep slopes do not normally reach bedrock, but have their shear planes in the regolith. However, on steeper slopes where soils are shallow, soil slips expose bedrock. These slips fail to revegetate, and the bedrock remains exposed by removal of further material, principally due to sheet wash and minor collapse. In this way the bare surface erodes back into the rock and at the same time increases in areal extent. Where such bare surfaces have eroded into a stream course, gully erosion is initiated. On some very steep slopes and in numerous gorges the end result of this sequence is a series of large bare rock faces on which it is impossible to re-establish a vegetative cover.

Vegetation

The vegetation consists mainly of pasture in association with manuka. The manuka may be scattered throughout the pasture, or as is often the case it occurs in small blocks. There are also some areas of mixed indigenous scrub and remnant podocarp-hardwood forest, most of which has been logged. This pattern of vegetation is indicative of a number of development and reversion cycles.

On Mahia Peninsula, in addition to manuka, both gorse and tauhinu are scattered throughout the pasture. The gorse occurs in the north-east near Table Cape and the tauhinu is more common in exposed coastal localities. Also on Mahia Peninsula is one of the larger remnants of forest occurring on this suite. It consists of about 340 ha of lowland podocarp-hardwood forest (with a significant number of coastal species) which has previously been logged, so that today it is dominated by a canopy of tawa with a reduced number of podocarps. Other significant areas of forest are at Ruakituri (a mixture of podocarp-hardwood and hardwood forest) and 6 km west of Willowflat (hardwood forest).

Land Use and Land Management

Much of the grazing in this suite is semi-intensive to extensive. In addition to sheep and cattle, goats are also farmed, particularly on Mahia Peninsula. Scrub reversion is a problem, especially in areas of higher rainfall.

Areas that have eroded to bedrock are normally not fenced off and are managed without recognition of the erosion. These areas should be fenced and retired or planted with trees. Because of the permanent nature of the soil loss, areas that have the potential to erode to bedrock should also be planted or retired, and such areas presently in scrub should be retained.

Land Use Capability Units

Three LUC units have been defined on banded mudstone. On the basis of erosion potential and slope they are mapped as VIe4, VIIe2, or Vllel 1. The area of the suite on Mahia Peninsula could be regarded as a subsuite because of the coastal climate. In the north-west of the Region where banded mudstone is mantled by a significant depth of tephra the suite grades into LUC suite 11.

LUC unit VIe4 (10,680 ha)—Figure 46

VIe4 occurs north-east of Wairoa and on Mahia Peninsula. It consists of moderately steep to steep hill country which has a potential for moderate soil slip and slight sheet and gully erosion. Soil slips rarely reach bedrock and consequently re-grass within several years with the aid of oversowing and topdressing. The unit is subject to the high intensity rainstorms that are typical of the Northern Hawke's Bay coastal belt.

The soils include Pakarae hill soils, Mahoenui and Taihape steepland soils, and where Taupo Pumice is significant, Tutira hill soils and Hangaora steepland soils. These soils are generally moderately well drained and have a moderately high fertility. This hill country is used entirely for pastoral farming although some manuka occurs in most areas. The potential stock carrying capacity is 14 su/ha, although the present average is 9 su/ha. The site index for *P. radiata* is 30-32 m, which is high for hill country.

LUC unit VIIe2 (35,650 ha)—Figure 46

A more extensive LUC unit, VIIe2 is mapped throughout the northern part of the Region where slopes are longer and steeper than VIe4. Soils are therefore shallower and less fertile. With steep to very steep slopes and shallow steepland soils the erosion potential is now for moderate to severe soil slip, moderate gully and slight sheet. Soil slips now more commonly expose bedrock and are slow to revegetate. In the Tukemokihi district bedding is apparent at the surface and has a pronounced effect on the topography, forming a series of minor cuestas, the scarps of which have a high erosion rate.

Production potentials are down slightly from those of VIe4, to a stock carrying capacity of 12 su/ha and a site index for *P. radiata* of 28-30 m. With the increase in erosion potential soil conservation measures are increasingly important. Apart from open planting of trees, stream planting to prevent gullying and block planting of the more severely eroded areas are particularly important.

LUC unit Vllel 1 (5,790 ha)—Figures 47, 74

Where slopes are oversteepened as bluffs or gorges, such as along the Waiau River, in the headwaters of the Mangaaruhe River and on the east coast of Mahia Peninsula, soils are so shallow that slipping leads to the development of large areas of bare rock. These areas, once established, continue to enlarge at their margins by further slipping and falling of rock. Rather than weathering to form a medium for the establishment of vegetation the bare faces are maintained by continual sheet wash. Once this situation has developed the area is practically useless in a productive sense, and establishment of vegetation is extremely difficult. These gorges and bluffs are mapped as Vllel 1 where significant areas of uneroded ground still exist and a productive land use is still possible. Without soil conservation measures there is a potential for very severe to extreme soil slip erosion and moderate gully erosion. Where the extent of the bare rock faces prevents a productive land use the area is mapped as VIIIe2. Normally, because of scale, such areas are too small to map. However along the gorge of the Waiau River Vllel 1 and VIIIe2 are mapped as a complex.

Vllel 1 is presently used for extensive grazing, however erosion control forestry is necessary for the major part of the unit, only small areas being able to sustain continual grazing. In the most eroded areas it may be necessary to encourage the regeneration of an indigenous cover. The grazing potential of Vile 11 is very low at 5 su/ha, while the forestry potential is medium with a site index for *P. radiata* of 27-29 m.

On Mahia Peninsula banded mudstone forms coastal cliffs (540 ha) which are mapped as VIIIe3 (Figure 84). Much bare rock is exposed and erosion consists of sheet, gully and rock

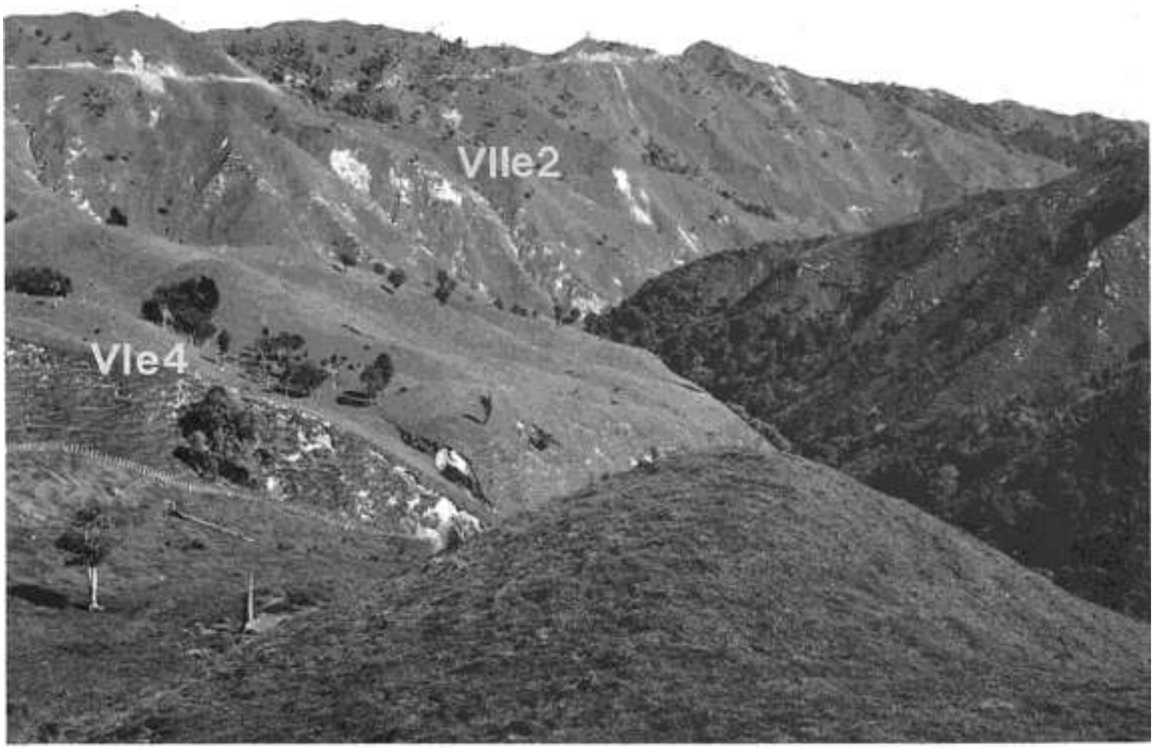


Figure 46: VIIe2 in background, VIe4 in foreground. Mahia Peninsula. Nl 17/260745, looking south-west.

fall. Some tauhinu and grasses have colonised favourable sites.

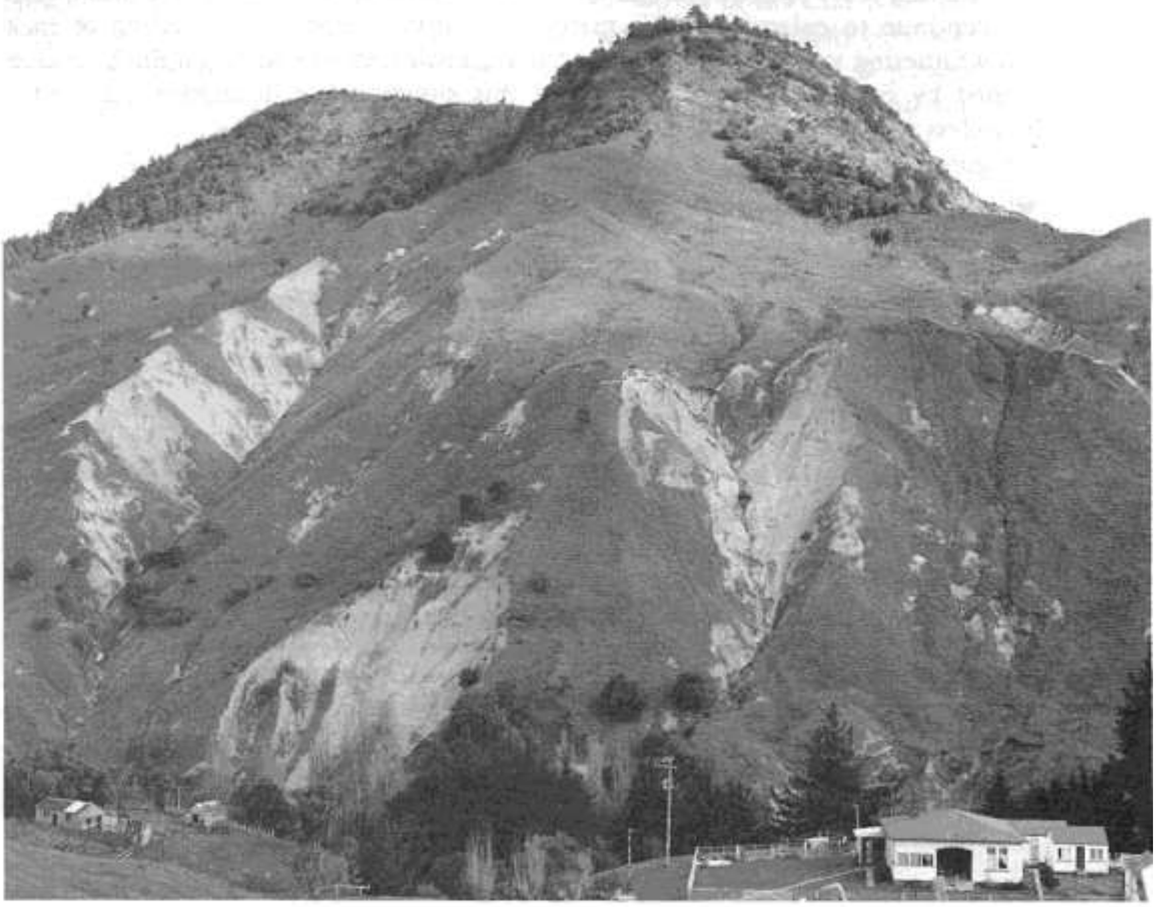


Figure 47: VIIe11. Erepeti Road, Ruakituri Valley. N105/739284, looking south.

LUC SUITE **8:** SILTSTONE HILL COUNTRY

The hill country around Wairoa has long been recognised as an area with high rates of soil slip erosion. This is apparent not only from historical records but also from hill slope morphology. This hill country has been defined by a suite of two LUC units: VIe7 and VIIe4. The suite is centred on Wairoa, forming the majority of the coastal hill country between the Waikari River in the south-west and Nuhaka in the north-east, and extending inland between 5-20 km (Figure 48). The area of the suite is 50,590 ha or 4.4% of the Region.

The suite consists of moderately steep to steep hill country formed from Tertiary and Quaternary siltstones. High intensity rainstorms are characteristic of the area (Soil Conservation and Rivers Control Council 1957), and records show that those of sufficient significance to affect farm management through erosion occur approximately every 3-5 years. Erosion therefore is a major feature of the suite, and the major limitation to use. The two LUC units, VIe7 and VIIe4, are separated on the basis of slope, which is the main factor governing the difference in erosion potential between the two units.

In some areas the hills are associated with narrow alluvial valleys, usually mapped as IIIwl or Ills 3. Small areas of rolling to strongly rolling slopes, usually ridges or low spurs, have a shallow mantle of rhyolitic tephra. These areas are much less eroded than the surrounding hills and are mapped in LUC suite 11.

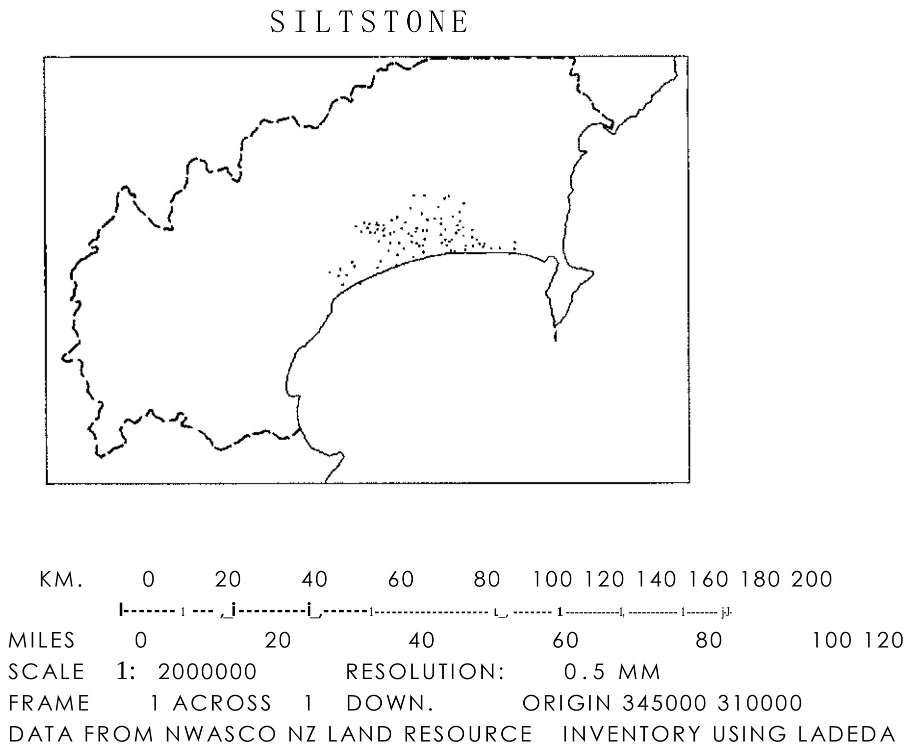


Figure 48: Location of LUC suite on siltstone hill country.

Climate

The most important aspect of the climate, in terms of land use, is rainfall variability. This typically includes both droughts and high intensity rainstorms. The annual rainfall for the area of the suite ranges from approximately 1200 mm near the coast to 1600 mm inland. There is a winter maximum and spring minimum which is more pronounced near the coast, although heavy falls may occur at any time.

Rainfall intensities from two climatological stations are given in Table 22 (New Zealand Meteorological Service 1983a).

Table 22: Maximum rainfall intensities

Climatological Station	Maximum 1-day rainfall (mm)	Maximum 2-day rainfall (mm)
Wairoa	194	252
Frasertown	185	267

Storms however may be very localised and of short duration. Because of the distance between recording sites such rainfall intensities may not be accurately recorded. Catchment board records show that a figure of 252 mm in 5 hours has been recorded in the Kiwi Valley (1977) and 325 mm in 3 hours at the head of the Waiatai Valley (1970) (pers. comm. Hawke's Bay Catchment Board).

Droughts, although not as severe as those at Napier, are still a significant feature of the climate and affect plant growth and farm management on a regular basis.

The climate is generally warm with mild winters. Sunshine hours are high (50% of possible), and frosts infrequent. The main wind directions are from the north and south, with winds from the south and east bringing the heaviest rainfalls.

Rock Type

The rock types in this suite are Tertiary and Quaternary in age and are among the youngest in the Region. They consist mainly of Waitotaran and Nukumaruan siltstone. The siltstone is generally soft and massive, exhibiting limited jointing, with occasional sandy beds. (Moore (1979b, 1979c) uses the more general term mudstone.) The youngest and softest material occurs towards the coast.

The area was originally mantled by a number of shallow tephras, the latest of these being Taupo Pumice. However today this has largely been removed by erosion, especially from the steep upper slopes. Shallow tephra is now present only on ridges, and the less steep lower slopes not affected by erosion. (The lower slopes are generally mapped in LUC suite 11.) There is an increase in the amount of tephra in the north-west of the suite.

A significant proportion of the soil-forming material consists of colluvium (usually associated with the class VI unit). This colluvium (regolith debris) occurs in basins at the foot of the steep upper slopes, and is indicative of the high erosion rate within the suite. It consists of a mixture of soil, tephra and weathered rock.

Soils

The soils in this suite consist of both hill soils and steepland soils. They belong to a number of different soil groups, dependent upon parent material and rainfall. When the parent material is siltstone the soils are either intergrades between yellow-grey earths and yellow-brown earths (drier areas near the coast), or yellow-brown earths (moist areas further inland). Yellow-brown pumice soils have formed where there is a shallow mantle of Taupo Pumice. Areas of colluvial soils occur in all these soil groups. The soils in this suite are from the Wairoa County Survey (Rijkse unpublished) and include the following series: Atua, Taihape, Whangaehu and Waitaha (intergrades between yellow-grey earths and yellow-brown earths); Pakarae and Mahoenui (yellow-brown earths); Gisborne, Tiniroto and Hangaroa (yellow-brown pumice soils).

The soils are generally moderately well to well drained and friable. The yellow-brown earths and the intergrades between yellow-grey earths and yellow-brown earths are of medium natural fertility, while the yellow-brown pumice soils are of lower fertility. Soil depth is related to slope; hill soils are generally deep (>1 m), while steepland soils are shallow (50-60 cm).

Topography

This is a hill country suite where slopes are moderately steep to very steep. The altitude range of these hills is from near sea level at the coast to approximately 430 m inland. They consist of well dissected ridge systems, from which run numerous secondary ridges or spurs. Ridge crests are narrow near the coast, becoming broader and more rounded inland, where a mantle of tephra has accumulated.

The Wairoa district has been subject to considerable uplift since the middle Pleistocene (Kamp 1982). This has led to downcutting by streams, and relatively high erosion rates. Hill slopes within the suite have two distinct forms. Higher inland areas, mainly in the vicinity of Cricklewood Road and Titirangi Road, have relatively long planar slopes leading directly into incised streams. Erosion debris therefore, on reaching the base of a slope, enters directly into a stream course. By contrast the lower coastal hills and those east of the Wairoa Valley have a characteristic concave profile consisting of two distinct slope components. In these areas rivers and streams have built up terrace systems. Erosion debris from the hills has therefore accumulated as colluvium on these terraces. The concave slope profile consists of a steep upper slope, below which is a significantly less steep colluvial foot slope. There is a distinct slope change between these two hill slope components which marks the boundary between the true hill slope with steepland soils, which is the source of the majority of soil slips, and the accumulation zone where the erosion debris has collected. In many areas where ridges run parallel these accumulation zones form colluvial basins. The surfaces are broken and poorly drained in comparison with the upper slopes where soils are shallow and excessively drained. During summer this moisture difference is very evident and marks the change of slope.

Erosion

This characteristic slope profile is evidence of a long and continuous history of erosion. Removal of the indigenous forest and scrub cover has however led to greatly increased rates of erosion, so that today very few areas of a hillside are uneroded. Erosion is a dominant feature of the landscape and and has major effects on land use, both present and long term.

The major erosion type is soil slip. Sheet and tunnel gully erosion are also present, with sheet erosion occurring mainly on the steep upper slopes and tunnel gullies occurring on the lower slopes, either in the colluvium or in the tephra mantling stongly rolling slopes. The majority of soil slips occur on the steep upper slopes where the shear plane is normally at or near the contact between the soil and the relatively impermeable siltstone. In contrast to these "shallow" soil slips those on strongly rolling to moderately steep slopes are somewhat deeper. However here, because of the greater depth of weathering, the shear planes do not reach bedrock.

A soil slip characteristically consists of a slip scar (source area) often just below a ridge, and a long debris tail (Figure 55). At the time of movement the debris is a highly fluid mixture of soil, other regolith material and pasture. The debris travels for considerable distances down slope of the slip scars and cover the existing pasture. (Because of the method of movement such soil slips would better be described as debris flows.) It is this debris that accumulates on the lower colluvial slopes, building up quite wide depositional surfaces in some cases. The debris, being a mixture of soil and weathered material, soon regrasses (within 2-3 years). However the slip scars high up on the slope remain bare for much longer (approximately 10-15 years), and when they do eventually regrass do not have the fertility or moisture retention of uneroded areas (Douglas *et al.* 1986).

The incidence of soil slip erosion in this suite is greater than in any other in the Northern Hawke's Bay Region. This is due to a combination of factors including the high weathering rate of the soft siltstone, steep slopes, recent uplift and the incidence of high intensity rainstorms.

Soil slip erosion is usually triggered by rainstorms. These may be high intensity rainstorms of varying duration, or they may be rainfalls of much lower intensity if soil moisture conditions are already high as a result of a prolonged "wet period". Droughts are thought to increase susceptibility to erosion by allowing water to enter the regolith to a greater than normal depth because of the drying and cracking that occurs.

An indication of the effect of high intensity rainstorms can be gauged from two such storms centered just west of Wairoa which occurred in February and April 1977, with 48 hour rainfalls of 493 mm and 272 mm respectively. Hawke's Bay Catchment Board estimates on the combined effect of these two storms indicate that on the worst affected property slips covered 21% of the hill area (Eyles and Eyles 1982).

Earthquakes are also a contributing factor to erosion. They may actually shake the ground sufficiently to cause soil slips at the time of the earthquake or they may produce cracks and fissures which allow increased infiltration leading to slipping at a later date. Both of these effects have been described by Ongley (1937) after the Wairoa earthquake of 1932. He described the worst affected area as being 5 km north-east of Wairoa, between Clydebank and the Waiatai Valley. Here the hills had "the turf detached from the underlying bed of pumice sand, torn into strips, and moved down from the crest in shallow slips". According to one local farmer the earthquakes of 1931 and 1932 initiated a cycle of erosion in the district (Hawke's Bay Catchment Board records).

Vegetation

Pasture is the dominant vegetation. At the time of mapping pasture occupied 33% of the suite, 64% consisted of pasture with a minor scrub component (mainly manuka) and 3% was scrub. Rushes are common on the poorly drained colluvial deposits. Blackberry is common throughout the pasture, but is rarely of sufficient areal extent to be recorded. Remnants of indigenous forest are also too small to be recorded. Only minor changes have occurred since mapping, mainly some clearance of scrub and the establishment of several small areas of exotic forest near Frasertown and Ohinepaka. Despite the problems of erosion there is an obvious lack of trees planted for soil conservation.

Land Use and Land Management

Land in this suite is mainly used for pastoral purposes. Sheep are grazed on the steeper hills and sheep and cattle on the easier hills. Goats are managed for weed control, principally blackberry. Scrub reversion is a problem and, in addition to goats, spraying and burning is used for control. Pastures contain a high proportion of low producing grasses and other pasture weeds. More fertiliser and smaller paddocks would improve both pasture quality and pasture utilisation.

Forestry is a recent, and at present, very limited land use. The terrain, with steep narrow ridges, is not conducive to normal logging methods and cable logging may be necessary. Tree establishment on the shallow droughty soils of the upper slopes would be difficult. Goats and regrowth of blackberry also pose problems to seedling establishment.

Although erosion has not as yet affected the land use it does affect land management. Effects of erosion are numerous and include the following: loss of grazing through immediate loss of pasture and long-term loss of soil, stock losses, disruption of access tracks and bridges, siltation of stock ponds, loss of fences and siltation of drains. The result is a significant financial loss. The effects on farm management may last for a number of years.

In recognition of the high erosion rate and importance of this hill country, trials have been conducted jointly by the Soil Conservation Centre, Aokautere and the Hawke's Bay Catchment Board (as part of a national investigation) to assess the effect of soil slip erosion on pasture production. Measurements have been taken of pasture production on different aged erosion scars and other landform units to establish production losses due to erosion and the long-term rate of recovery (Douglas *et al.* 1986). Results from this study show that soil slip erosion limits pasture production. Recovery is most rapid in the first 10 years after slipping, and after 30 years there is no further increase in production. Measurements are also being taken to assess erosion rates (Trustrum *et al.* 1984). Initial results indicate that over 95% of the original forest soils have been stripped from the steep upper slopes (Trustrum pers. comm.).

This would indicate that erosion rates are among the highest in New Zealand for hill country affected by soil slip erosion. Equally, recovery rates would appear to be well above average.

As a result of concern over the limits that erosion poses to future production the Hawke's Bay Catchment Board is presently undertaking an evaluation of the soil conservation requirements of this area. Clearly an increased soil conservation input is required in land management. Options include: afforestation where appropriate, open planting of depositional areas, silt and water retention in gully floors, gradient control in water courses, closer subdivisional fencing, oversowing and topdressing after erosion-producing storms (Black and Cairns 1983). At present such techniques have not been widely adopted by land owners. The increased use of tree and shrub species would appear to be necessary, and the McRae Trust, a hill country property near Frasertown, is being used by the board as a demonstration trial for planting various tree and shrub species. Given existing land use, some form of two-tier farming may offer the best prospects.

Land Use Capability Units

The two LUC units in this suite are defined on erosion potential. VIe7 has a potential for severe erosion, while for VIIe4 the potential is very severe. Slope is used to identify the two LUC units as there is a direct relationship between slope and erosion potential.

At the 1:63,360 scale of mapping the two very distinct components of the hillslope cannot be separated. For this reason colluvial foot slopes are mapped in VIIe4, where at more detailed scales these areas could be identified separately as VIe7.

LUC unit VIe7 (35,250 ha)—Figures 17, 49, 50, 70

VIe7 is mapped on moderately steep to steep slopes where there is a potential for moderate to severe soil slip erosion and slight sheet and tunnel gully erosion. Also included are significant areas of rolling to strongly rolling colluvial foot slopes. Slopes are generally short in length with rounded ridge tops. Many of the easier slopes, especially inland, have a shallow and patchy cover of rhyolitic tephra. Here soils are those of the Tutira, Tiniroto or Gisborne series, and on steeper slopes Hangaroa series. Where the tephra is absent (especially near the coast) soils include those of the Pakarae and Atua series, and on steeper slopes Taihape, Whangaehu, Waitaha and Mahoenui series.

Soil slips rarely reach bedrock but form in regolith to produce large quantities of debris which is deposited on the colluvial foot slopes. A common practice is to disc these lower slopes for pasture renewal and at the same time smooth out the uneven surface and improve the poor drainage that has been caused by this debris.

Potential stock carrying capacity is high for hill country, at 17 su/ha, although the present average is only 10 su/ha, and site index figures for *P. radiata* are also high at 29-32 m. The most productive part of the LUC unit is the colluvial foot slope.

LUC unit VIIe4 (15,180 ha)—Figures 51, 70

Steep to very steep slopes have a potential for very severe soil slip erosion, moderate sheet erosion and slight gully erosion. With increased erosion potential and lower productivity these areas are mapped as VIIe4. The slopes are longer than those of VIe7 and ridges are narrower. In areas towards the coast VIIe4 includes some colluvial foot slopes, while in inland areas slopes lead directly into streams which are actively downcutting, leading to a high incidence of slipping along these channels.

The slip scars revegetate more slowly than in the case of VIe7, since soils are so shallow that slip scars may expose bedrock. Pastures dry off more quickly leading to an increase in sheet erosion. Soils are steepland soils and include those of the Whangaehu, Waitaha, Mahoenui series and, where shallow rhyolitic tephra is present, the Hangaroa series.

The hills are grazed in conjunction with VIe7 as both LUC units are associated in the landscape. Paddocks often include both LUC units within their boundaries. Potential stock carrying capacity is down to 12 su/ha with a present average of 7 su/ha. Site index for *P. radiata* is 27-31 m. Soil conservation measures for VIIe4 are less clear than those for VIe7. The value of open planting trees such as poplars is in some doubt because of the difficulty of establishment on the shallow, droughty soils. However recent trials indicate that species of eucalypts and acacia are suitable for such conditions.

Between Wairoa and the mouth of the Waikari river the hills in this suite terminate in a series of coastal cliffs. Because of scale only the largest of these (160 ha) have been mapped. These cliffs have been mapped as VIIIe3 and consist of vertical or near vertical bare rock faces, between 60-200 m in height. Vegetation is very restricted and consists of tauhinu and grasses. Erosion is presently limited to slight to moderate rock fall, sheet and gully, with very little recession of the cliff face. However in the past, collapses of the cliff face have occurred such as one 5 km south-west of Wairoa during the 1932 earthquake. This collapse was 600 m long and extended inland for 300 m (Ongley 1937).

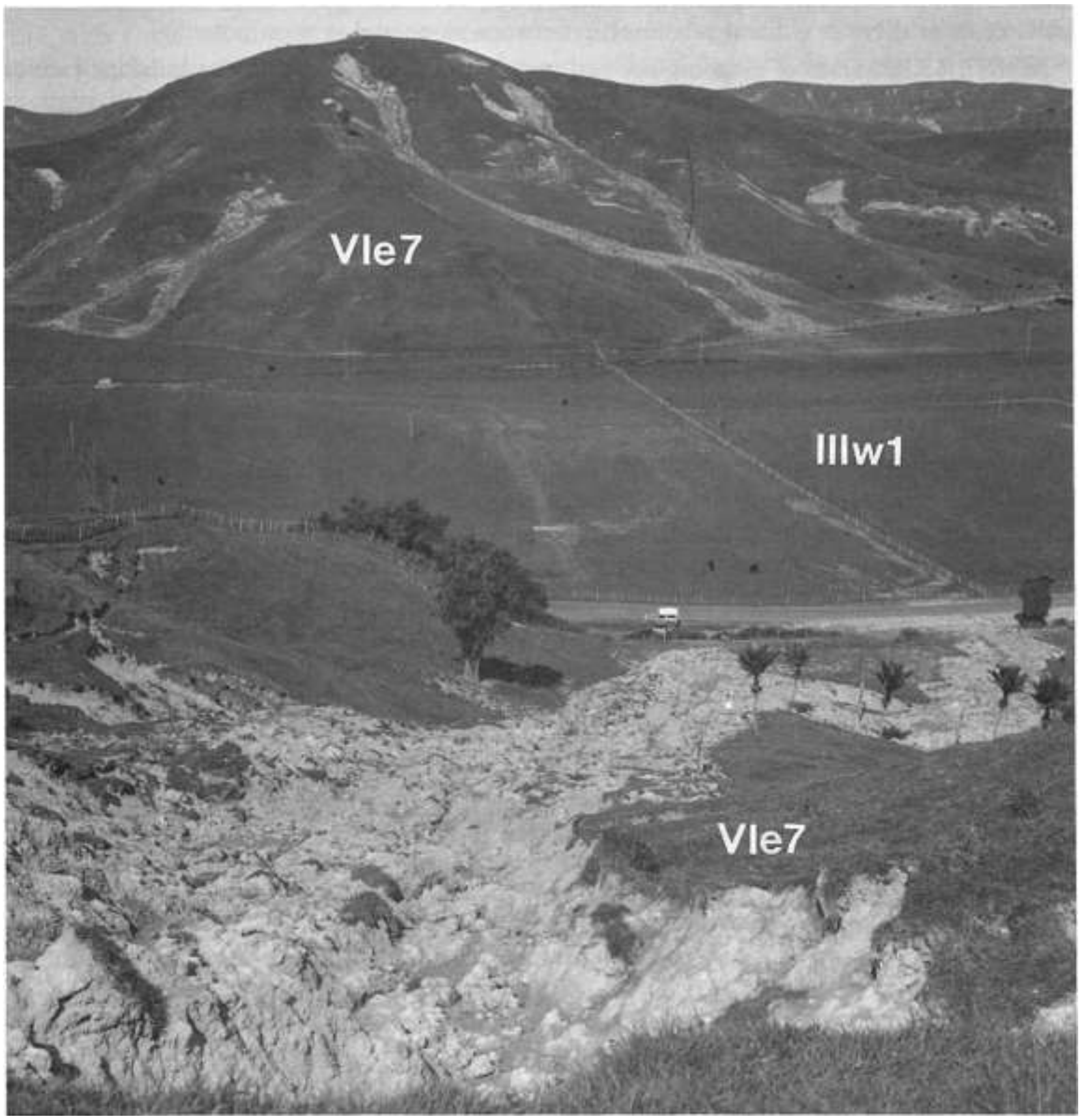


Figure 49: VIe7. State highway 2, east of Wairoa. Nl 16/870949, looking south. Taken in 1974. IIIwl flats in centre (LUC suite 1).

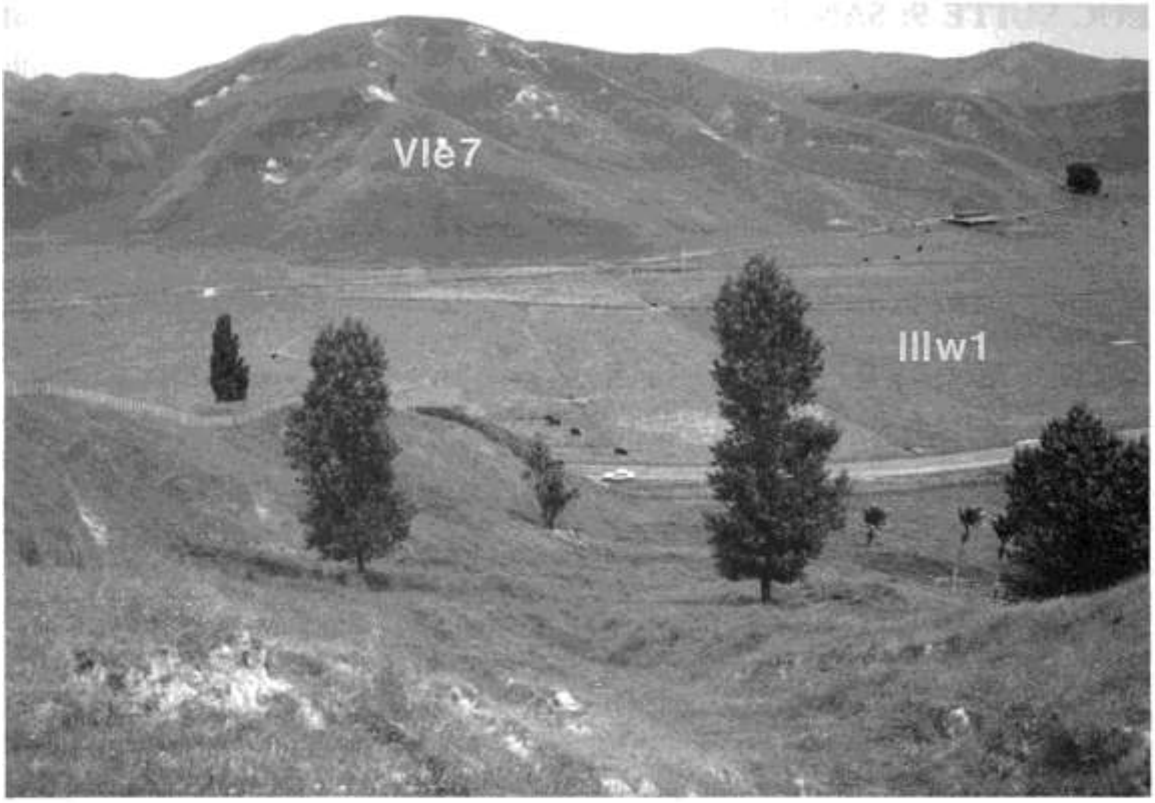


Figure 50: VIe7. State highway 2, east of Wairoa. N116/870949, looking south. Taken in 1986. IIIw1 flats in centre (LUC suite 1).

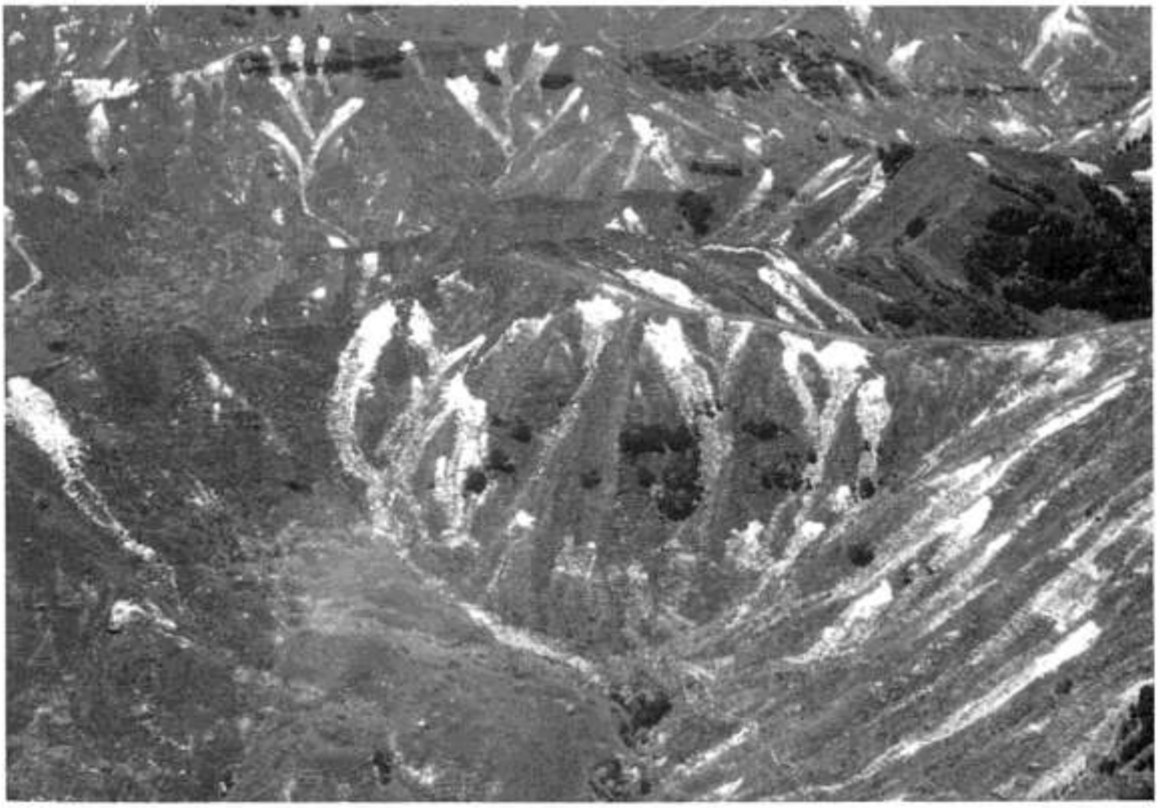


Figure 51: VIIe4. North-east of Wairoa. Effects of 1974 storm. N116/910000 approx., looking south-east. Photo: N A Trustrum

LUC SUITE 9: SANDSTONE HILL COUNTRY

This is a diverse suite of hill country units found extensively throughout the Region, with the exception of upland and mountainland areas and the dry hill country immediately north-west of Napier (Figure 52). The suite consists of 8 LUC units comprising 88130 ha or 7.7% of the Region. All units in the suite are mapped on sandstone, however they can be divided into two groups or "subsuites" according to the nature of the sandstone. Within both sub-suites the LUC units are defined on the basis of slope and erosion potential.

There are wide annual rainfall and altitudinal ranges throughout the suite with one subsuite occurring in lower, drier areas and the other subsuite being more common at higher altitudes where rainfall is also higher.

In some instances the sandstone is overlain by a shallow and patchy layer of tephra, principally Taupo Pumice. However this does not mask the properties of the sandstone and for this reason the units are better described in this suite than in LUC suite 11. Soils are mainly yellow-brown earths, but where tephra is present yellow-brown pumice soils have developed.

LUC units in the sandstone suite are characterised by lower natural fertility than units in other hill country suites, and for this reason the suite contains a higher percentage of scrub than other hill country suites. The main erosion type is soil slip, with some minor sheet erosion occurring in drier areas. The low natural fertility of the sandstone is reflected in the slow recovery rate of the slip scars.

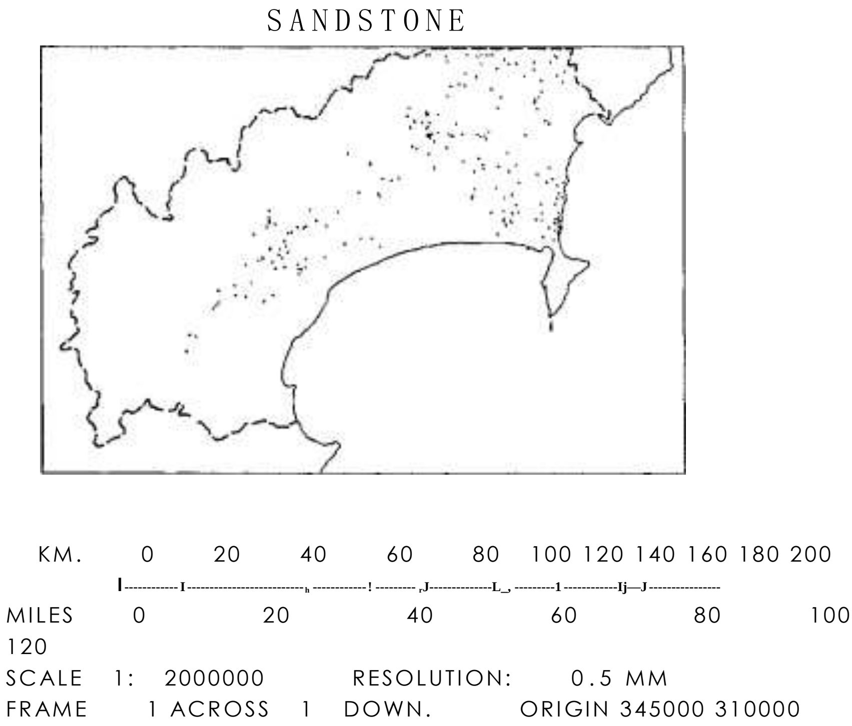


Figure 52: Location of LUC suite on sandstone hill country.

Climate

Because of the wide distribution of this suite there is a correspondingly wide range of climatic conditions. Annual rainfall ranges from 1000 to 2800 mm p.a. and altitude ranges from sea level to 900 m. Droughts are common in the lower rainfall areas which affect plant growth during summer, while with increasing altitude lower temperatures reduce plant growth during winter.

Frosts are common in upland inland areas and occasional snow-falls occur. Where scarps and bluffs occur these are often exposed sites which experience strong winds.

Rock Type

Although the rock type for all the LUC units in this suite is sandstone there is considerable variation as to the type of sandstone. This ranges from massive to well-bedded, and from calcareous to siliceous. In addition there is variation in hardness from moderately soft to hard. However all these sandstones are Tertiary and most are Miocene in age.

The banded sandstones consist of alternating beds of sandstone and mudstone. There is considerable variation in the thickness and spacing of the sandstone beds but they are always dominant over the mudstone in the formation. In extreme cases the mudstone beds may be so thin as to be inconspicuous. In some cases, notably Whakapunake and the Maungaharuru Range, limestone beds also occur within this sequence. Where the mudstone beds are dominant over the sandstone beds the rock type is mapped as banded mudstone (see LUC suite 7).

The dip of these beds ranges from nearly horizontal to steep with most between 10-20° (Moore 1979a, 1979b, 1979c). The uplift and tilting of these beds has, in many cases, led to the formation of dip/scarp or cuesta topography. The scarps, consisting of long steep slopes, and formed on the alternating beds are mapped within this suite. The dip slopes, which are normally parallel to the bedding and much less steep, often have a mantle of tephra and so are mapped in LUC suite 11.

In the north of the Region, in the Rere-Ngatapa district, the bedding is not as pronounced and in places may be regarded as massive. Consequently cuestas give way to typical hill slope topography. In the vicinity of Rere much of the sandstone is calcareous.

As with a number of other hill country suites there is a shallow mantle of rhyolitic tephra on less steep or uneroded slopes. Because the LUC units in this suite are generally more stable than those formed from mudstone, here there is somewhat more tephra preserved. The depth of tephra also increases towards the west. Nevertheless the tephra is still sufficiently shallow and patchy for the properties of the underlying sandstone to be expressed. Only where the tephra mantle is complete and moderately deep (approx. >30 cm) is it thick enough to mask those properties. LUC suite 11 is mapped where tephra exceeds this thickness.

Soils

The majority of soils are steepland soils related to yellow-brown earths, and on less steep slopes their hill soil equivalents. These soils have developed in the absence of tephra. Where tephra is present yellow-brown pumice soils and related steepland soils have developed. Such soils are more common towards the west, although where tephra is patchy a complex of yellow-brown pumice soils and yellow-brown earths occur. In an area west of the Gisborne Plains in the Ngatapa district soils are composite yellow-brown pumice soils on yellow-grey earths.

The suite is mapped in the north-eastern and central areas of the Region. In the north-east soils are taken from the General Survey (New Zealand Soil Bureau 1954) (43%), while in the central area soils have been mapped using the Wairoa County Survey (Rijkse unpublished) (51%). A small area is covered by the Mid Hawke's Bay survey (Pohlen *et al.* 1947) (6%).

Developed on hard sandstone these soils are shallow and of low natural fertility. In high rainfall areas leaching further reduces the soil nutrient status, although generally the soils are well drained.

Topography

This is a hill country suite and slopes range from moderately steep to very steep (21°->35°). The terrain includes typical hill country landforms, consisting of alternating ridges and valleys. This hill country is common west and south of Gisborne. Other landforms are scarps, bluffs and gorges. Here slopes are long and particularly steep with numerous rock outcrops. In the case of one LUC unit (VIIe8) the landform is a striking series of cuestas with near vertical scarps and relatively steep dip slopes.

Erosion

The characteristic erosion types in this suite are soil slip and sheet. The majority of slopes are steep to very steep and the soils that have developed are shallow, with the underlying sandstone within 20-30 cm of the surface. Soil slips are correspondingly shallow with shear planes occurring along the contact between soil and bedrock. The relatively hard and infertile nature of the sandstone means that the slip surfaces weather only slowly, by contrast with mudstone, and the scars remain unvegetated for longer. Therefore, although the rate at which soil slips occur on sandstone may be lower than on mudstone, this is substantially offset by the slower recovery rate on sandstone.

The potential for soil slip erosion increases with slope angle until the soils become so shallow that the sandstone outcrops at the surface. Under these circumstances the potential for soil slip erosion decreases.

On such steep slopes the shallow soils have a poor moisture holding capacity. Where these slopes are in pasture, overgrazing or droughts reduce the pasture cover, exposing the soil to sheet erosion. Sheet erosion is more common in the lower rainfall (<1600 mm p.a.) areas of the suite.

On near vertical bluffs and gorges where the sandstone is bedded, erosion may take the form of rock falls which dislodge large blocks of sandstone.

Vegetation

The infertile parent material, steep slopes and cool wet climate have influenced the type and distribution of vegetation in this suite. Reversion of pasture is a major problem and this is reflected in the vegetation classes mapped. At the time of mapping, large blocks of scrub or fern accounted for approximately 38% of the vegetation while approximately 54% was dominantly pasture in which scrub or fern had established, either scattered through the pasture or in blocks too small to record separately. Very little pasture was unaffected by reversion. In addition, by far the majority of the pasture consisted of species which characterised it as low producing. Exotic forest accounted for approximately 4% of the vegetation.

The problems of reversion and a medium to high potential for the growth of *Pinus radiata* have led to a dramatic increase in the area of exotic forest in the last 10 years. However the picture for the remainder of the area is largely as it was; small areas of scrub clearance being offset by further reversion elsewhere. Only on the more fertile sandstones in the lower rainfall areas west of Gisborne are the pastures relatively free from reversion.

Land Use and Land Management

Exotic forestry is increasing at the expense of pastoral farming, and although this trend is expected to continue it is confined to the less fertile sandstones found in the higher rainfall areas, which mainly occur between Gisborne and Wairoa. The major area is the Wharerata State Forest which is north of Nuhaka. Smaller blocks are being planted by forestry companies and farmers.

Reversion is a major land management problem in areas still used for farming. Spraying and burning of scrub and fern are the most common techniques of control, although closer subdivision and increased fertiliser applications are also essential. In addition to sheep and cattle, goats are farmed in these areas. Grazing is extensive except on the more fertile sandstones west of Gisborne.

Erosion is generally less severe in this suite than in the mudstone and siltstone suites. This, together with the low productive potential for pastoral farming, means that soil conservation measures are rarely used. In forestry areas trees have had the added benefit of reducing erosion.

Land Use Capability Units

The LUC units in this suite can be divided into two groups or subsuites:

a. Calcareous sandstone subsuite

b. Non-calcareous sandstone subsuite.

The first consists of two LUC units, VIe8 and VIIe5. Here the sandstone is mainly calcareous and either massive or poorly bedded. The rainfall is 1000-1600 mm p.a. and reversion is not a problem. There is normally a shallow but patchy layer of tephra. In the second subsuite the sandstone is well bedded and usually non-calcareous, while very little tephra is present. Rainfall is 1600-2800 mm p.a. Natural fertility is lower and reversion rates are higher than in the other subsuite. There are six LUC units in this subsuite, Vie 14, VIIe9, VIIIe2, VIIIsl, and also VIsl and VIIe8 which although mapped on sandstone are not strictly part of this sequence but are included in the subsuite as the 'best fit'.

Both erosion and shallow infertile soils are major limitations in this suite, particularly in the second subsuite. Table 23 lists the potential stock carrying capacity and the site index for *Pinus radiata* for each of the LUC units. These figures are generally low for pastoral production and medium to high for forestry production, and show a gradual reduction in productive potential from VIe8 to VIIe9.

Table 23: Potential production data for LUC units on sandstone hill country

LUC Unit	Potential Stock Carrying Capacity (su/ha)	Site Index for *Pinus radiata* (m)
VIe8	11	30-32
VIIe5	11	25-30
VIsl	10	30-32
Vie 14	9	24-32
VIIe8	9	25-32
VIIe9	6	24-29
VIIIe2	unsuitable	unsuitable
VIIIsl	unsuitable	unsuitable

Calcareous Sandstone Subsuite

LUC **unit VIe8 (9,190** ha)—Figure 53

Most of this LUC unit occurs in the Ngatapa-Rere district where rainfall is 1000-1400 mm p.a. The sandstone is largely massive, although some bedding does occur. Much of it is calcareous and not quite as hard as that of the other subsuite. The unit forms hills with moderately steep to steep slopes.

Present erosion is slight to moderate soil slip and slight sheet, with a potential for moderate soil slip. Slips are shallow, exposing bedrock, and although slow to heal do so more quickly than those of the other subsuite.

Soils include Otamauri sandy loam, hill soil (composite yellow-brown pumice soil on yellow-grey earth) and Waihua steepland soils (steepland soils related to yellow-brown pumice soils). The hills are used for grazing, with manuka significant in some areas.

The potential stock carrying capacity is 11 su/ha and site index for *P. radiata* is 30-32 m.

LUC **unit VlleS (19,040** ha)—Figure 54

VIIe5 is mapped in association with VIe8, where slopes are steep to very steep and generally longer than those of VIe8. Soils are shallower although some tephra is still present. The main soils are Waihua steepland soils. The erosion potential has increased to moderate to severe soil slip and moderate sheet. Land use and vegetation are the same as for VIe8. In addition to the Ngatapa-Rere district, Vile 5 also occurs in the Raupunga-Waihua district. While the potential stock carrying capacity is the same as for VIe8, the site index for *P. radiata* is down to 25-30 m.

Non-calcareous Sandstone Subsuite

LUC **units VIel4 (17,130** ha)—Figure 55 and **VIIe9 (31,840** ha)—Figure 75

Both of these LUC units are mapped on banded sandstones (alternating beds of sandstone and mudstone where the sandstone beds dominate). VIIe9 is also mapped on massive sand-stone. The sandstone is harder and less fertile than that of VIe8/VIIe5 and this is reflected in the potential productivity figures (see Table 23). Vie 14 and VIIe9 are also mapped in higher rainfall areas (1600-2800 mm p.a.), which leads to leaching of soil nutrients. Reversion is a major problem with these units because of the low natural fertility. Potential stock carrying capacities are therefore low at 9 su/ha for VIel4 and 6 su/ha for VIIe9. Wharerata State Forest has been planted in response to problems of fertility and reversion. Production figures for forestry are generally medium and range from 24-32 m for VIel4 and 24-29 m for VIIe9.

As with the other subsuite the difference between Vie 14 and VIIe9 is based on slope and erosion potential. Vie 14 is mapped on moderately steep to steep hills where erosion potential is for moderate soil slip and slight sheet, whereas VIIe9 is mapped on steep to very steep hills, scarps and gorges where slopes are longer and soils shallower than those of VIel4. Erosion potential is for moderate to severe soil slip, slight sheet and slight gully.

Both Vie 14 and VIIe9 are mapped on the Wharerata hills and in the area to the west as far as Whakapunake, while VIIe9 is also mapped on the Te Waka and Maungaharuru Ranges, the gorge of the Mohaka River and in areas north of Wairoa, especially the Wharekopae-Tahunga district.

Soils are steepland soils related to yellow-brown earths, with small areas of yellow-brown pumice hill soils. Typical soils are Wharerata and Whangamomona steepland soils and Gisborne hill soils.

The problems of low fertility and reversion are reflected in the vegetation of the two units. Nearly all map units have a mixture of two or more of the following: low producing pasture, manuka, mixed native scrub associations and fern. Other vegetation classes include exotic forest and tauhinu.

Coastal cliffs (VIIIe3) occur along the coastline of the Wharerata hills. Only 60 ha of these were large enough to be mapped.

LUC **unit VIIIe2** (7**,380 ha)—**Figures 56, 70, 75

Where scarps and gorges become too steep for productive use they are mapped as VIIIe2. Here slopes are in excess of 35°, soils are very shallow with numerous areas of bare rock, and there is a potential for severe soil slip erosion and moderate gully and sheet erosion. Soils are steepland soils related to yellow-brown earths developed on banded sandstone with some limestone beds. Vegetation is a mixture of manuka, mixed native scrub associations and low producing pasture. This cover should be maintained and encouraged to regenerate in order to reduce erosion rates.

VIIIe2 occurs scattered throughout the Region. In the ranges it has been described in LUC suite 11, in the low rainfall areas north-west of Napier it has been described in LUC suite 10 and in the Putere district it is mapped in association with Vllel 1 as part of LUC suite 7. Elsewhere, particularly on the scarp of the Te Waka and Maungaharuru Ranges and the gorge of the Mohaka River VIIIe2 is part of this suite.

LUC **unit VIIIsl (1,310 ha)—**Figure 57

Sheer bluffs of massive sandstone are mapped as VIIIsl. Here erosion potential is only slight due to the very hard, massive nature of the sandstone. The main limitations are a lack of soil and the precipitous slopes. The surface is mainly bare rock with limited areas of very shallow soil which support manuka or stunted beech forest (mainly mountain and red beech).

This unit is mapped along the lower reaches of the Te Hoe River, near its confluence with the Mohaka River. Rising 450 m above the surrounding hills are a series of spectacular bluffs, one of which has a flat top and is known as Te Kooti's Lookout.

LUC **unit VIsl (150 ha)—**Figure 58

This unit is restricted to two small areas, one at Mahanga on the coast north of Mahia Peninsula, and the other at Willowflat where the Willowflat Road crosses the Mohaka River. It is mapped on old slump surfaces that have stabilised and have no likelihood of further activity.

At Mahanga the unit consists of debris that has fallen from the steep slopes above and come to rest on the coastline. There is no prospect for further movement of this debris, it having reached a stable angle of repose. The terrain consists of short strongly rolling to rolling slopes with numerous sandstone boulders at the surface. Ashcott soils (yellow-brown earths) have developed on the sandstone debris. The unit is well drained, has no erosion potential and the vegetation is entirely pasture.

The other area of VIsl, at Willowflat, also consists of slump debris from surrounding slopes. The debris has come to rest on a terrace above the Mohaka River and is now quite stable. Slopes are undulating to rolling with numerous sandstone boulders littering their surfaces. The soil is Tuai sand (yellow-brown pumice soil) developed on rhyolitic tephra. The presence of this tephra indicates that this slump occurred at least several thousand years ago and that the debris has since been stable. The unit is well drained, has no erosion potential and is in pasture.

In both areas the uneven nature of the surface and the presence of surface boulders prevent cropping, and together with soil fertility they are the major limitations to use. The potential stock carrying capacity figure is low at 10 su/ha and the site index for *P. radiata* is 30-32 m.

A number of other ancient slump features which have long been stable, such as one at Putere, have been mapped as VIel. In these cases slopes are somewhat steeper, being strongly rolling to moderately steep. This has led to the potential for slight soil slip and tunnel gully erosion which is the reason for the 'e' classification. However, because of the relatively low fertility of the yellow-brown pumice soils and because the erosion potential is only slight, such areas may be better classified as Vis (see also VIel p.125). Deep-seated movements which are presently stable but which have a potential for further movement are mapped as VIelO (p.75).

LUC unit VIIe8 (2,030 ha)—Figure 59

This LUC unit consists of a single large map unit which is really an association of a number of LUC units. It has been mapped as a separate LUC unit because of the unique landform and because at the scale of mapping it was not possible to map the constituent LUC units. For these reasons VIIe8 does not fit well into any suite of LUC units. It has been included in this suite because of the banded nature of the rock type. It could equally well have been included in LUC suite 7.

The unit occurs north of Wairoa in the Mangapoike catchment and consists of a series of cuestas with long moderately steep dip slopes facing west and very steep scarp slopes facing east. The rock consists of alternating beds of mudstone and sandstone which impart a strong structural control on the landform that has developed. Bedding is parallel to the dip slope, so that where the uppermost bed is sandstone the surface is relatively stable, but where mudstone is the uppermost bed gullies, slumps and earthflows have developed. Many of these are ancient features although some are still active and there is always the potential for future activity. These dip slopes would be mapped as VIelO or VIIe6 where there are gullies, earthflow or slumps and VIel or VIe6 where there have been no deep-seated movements and soil slips are the only erosion form. The scarp slopes consist of beds of alternating sandstone and mudstone which would be mapped as VIIe2 where mudstone beds dominate, VIIe9 where sandstone beds dominate or VIIIe2 or VIIIsl on precipitous faces.

A range of soils have developed on this landform. They are classified as steepland soils related to yellow-brown earths, steepland soils related to yellow-brown pumice soils and yellow-brown pumice soils, and they included Wharerata, Mahoenui and Waihua steepland soils and Gisborne hill soils. The vegetation consists of low producing pasture with some manuka, fern and mixed native scrub associations mainly on the steep scarps. Rainfall is high at 2400 mm p.a.

The productivity figures are an average for the range of terrains that occur within this LUC unit. They are 9 su/ha for potential stock carrying capacity and 25-32 m for site index for *P. radiata.*

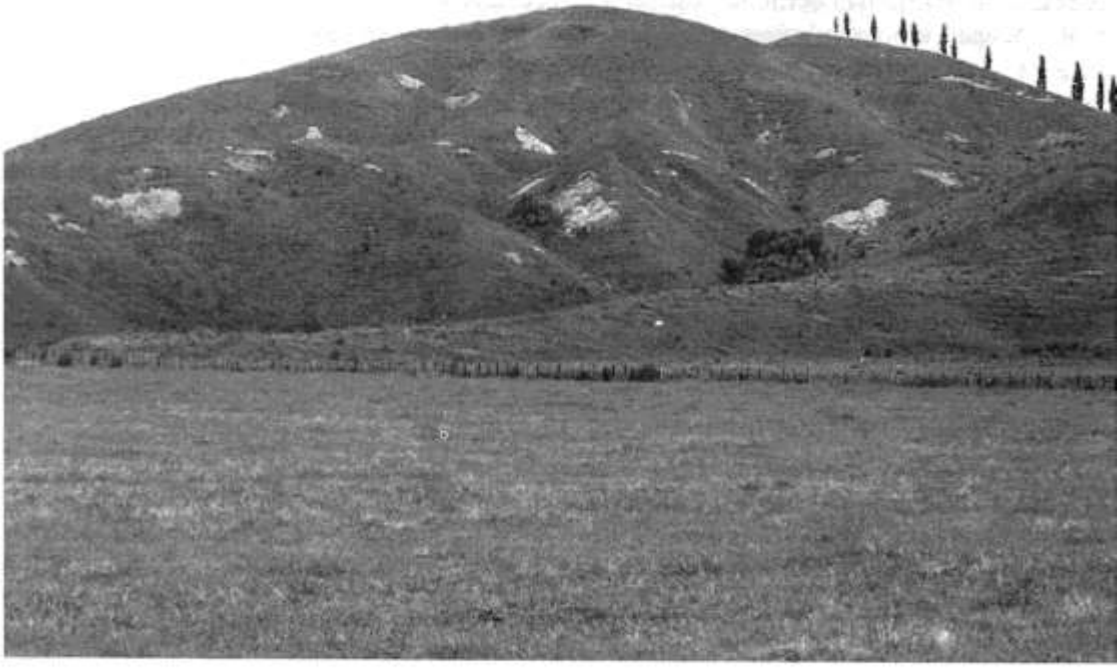


Figure 53: VIe8. Humphrey Road, west of Waipaoa. N98/275537, looking south.

Figure 54: VIIe5. South of Ngatapa. N97/199442, looking south.

Figure 55: VIe14. Wharerata hills. N107/285140, looking east.

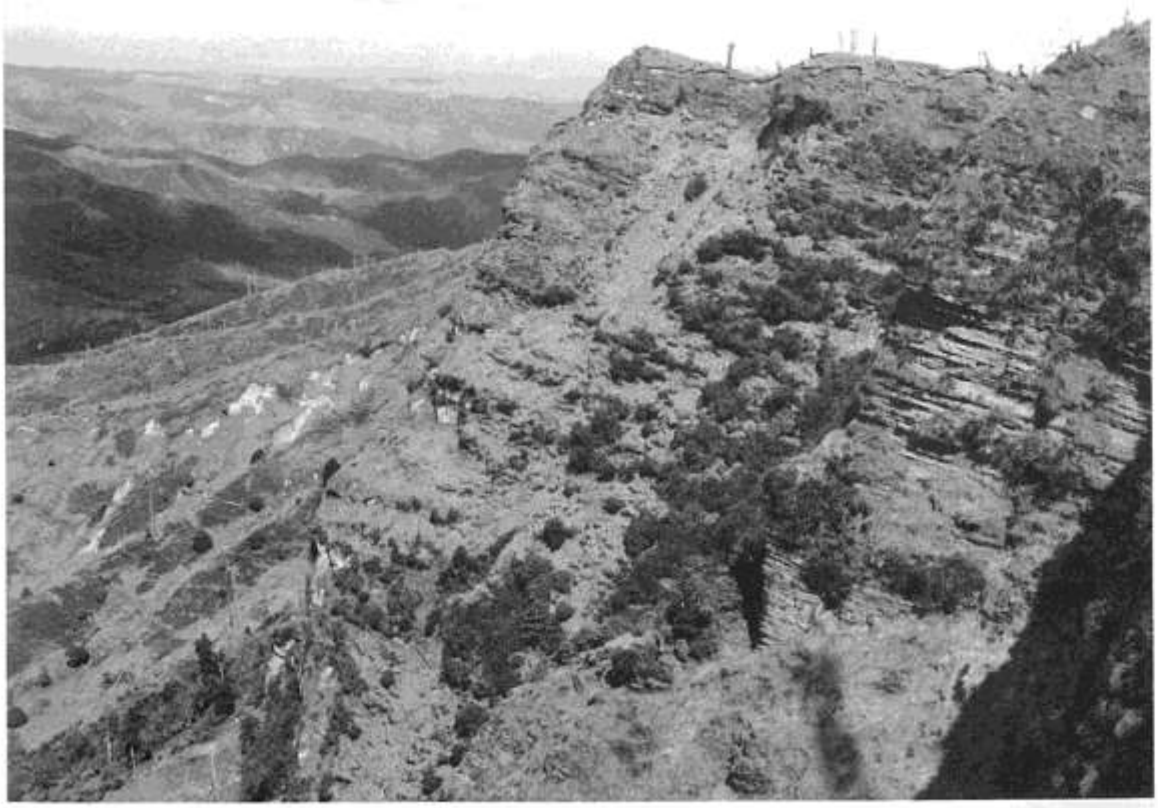


Figure 56: VIIIe2. Whakapunake scarp. N106/995180, looking south.

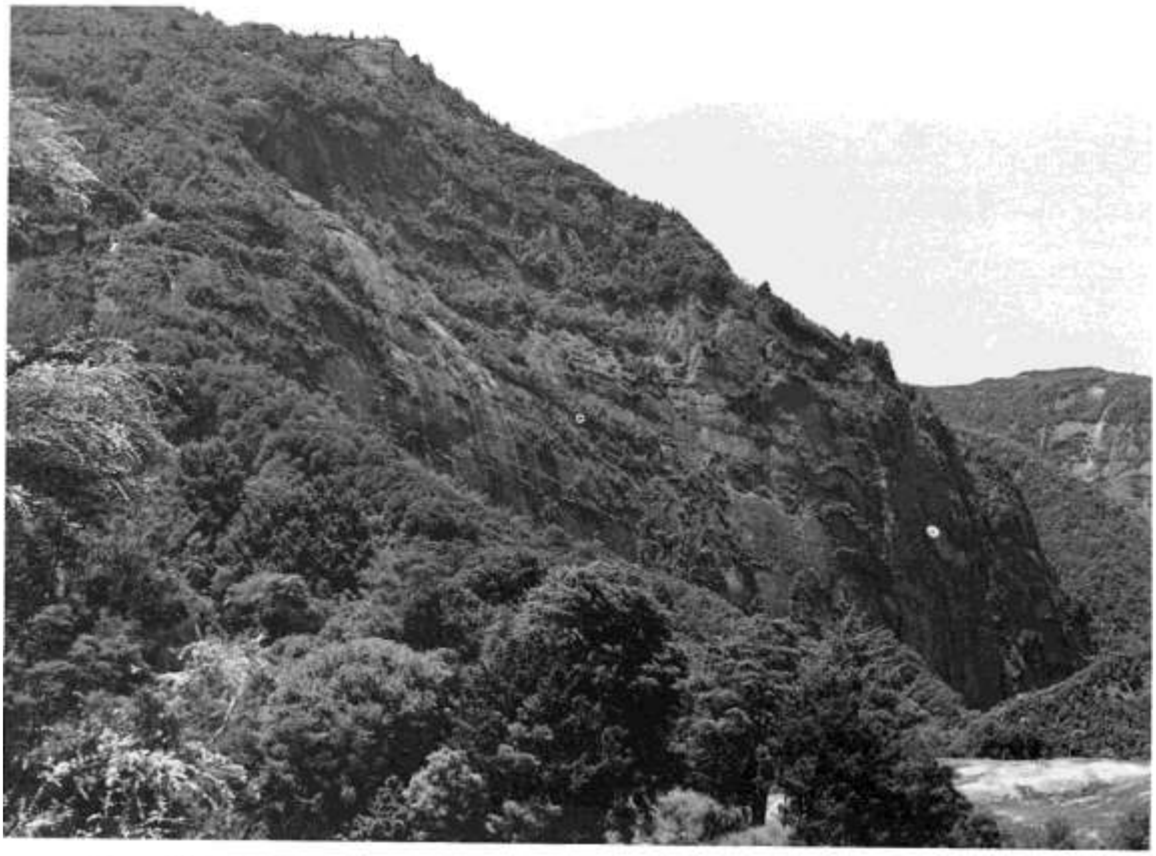


Figure 57: VIIIs1. Pie Cart Road, Te Hoe River. N104/233036, looking south-east.

Figure 58: VIs1. Mahanga Road, east of Opoutama. N117/262965, looking north-west.

Figure **59:** VIIe8. Mangapoike Valley, north-east of Frasertown. N106/060150, looking south.
Photo: N A Trustrum

LUC SUITE 10: LANDFORMS WITH A MANTLE OF LOESS

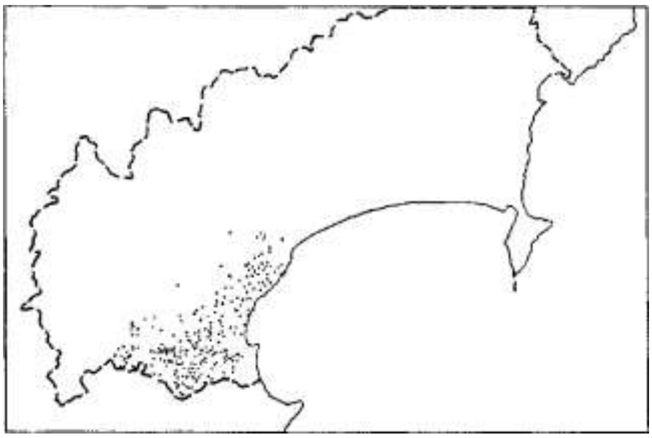
This is a large suite of 86,350 ha with 9 different LUC units which occupy 7.5% of the Region. The suite occurs in the south-east of the Region, from Napier as far north as Tutira and inland as far as a line from Waikoau running south-west to Rissington and Whanawhana (Figure 60). It comprises all the higher terraces, rolling downlands and hill country, but not including the Heretaunga Plains.

The LUC units in the suite are characterised by: an annual rainfall of 800-1200 mm, with periods of drought; a mantle of loess which overlies sandstones and siltstones interbedded with limestones and conglomerates; and soils that are yellow-grey earths, intergrades between yellow-grey earths and yellow-brown earths or related steepland soils. LUC units within the suite are defined on the basis of slope.

Climate, and in most cases erosion, are the major limitations to use. With a relatively low rainfall of high annual and monthly variability, periods of soil moisture deficiency are common, especially during the summer-autumn period. Plant growth can be seriously affected during this time, sometimes for up to 4 months. Erosion type and severity are dependent upon slope. Sheet, rill and wind erosion occur on areas subject to cultivation, and soil slip, sheet and tunnel gully erosion occur on steeper slopes.

At the northern and western margins of the suite the landscape has been mantled by tephra from a series of volcanic eruptions from the central North Island. These tephras have subsequently been eroded from the steeper slopes. The soils of the steeper slopes are therefore yellow-grey earths while those of the easier slopes are yellow-brown pumice soils and so are mapped in LUC suite 11.

LOESS



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MILES 0 20 40 60 80 100 120

SCALE 1: 2000000 RESOLUTION: 0.5 MM

FRAME 1 ACROSS 1 DOWN. ORIGIN 345000 310000

Figure 60: Location of LUC suite on landforms with a mantle of loess.

Climate

The annual rainfall is low within the area of this suite. It ranges from 800 mm near the Heretaunga Plains to 1200 mm+ at the northern boundary of the suite. However it is the high variability in rainfall distribution in time which is more important, as this has major effects on land use. Near Napier annual rainfall may vary from as low as 66% to as high as 176% of the annual average (Grant 1982). Rainfall is more variable here than in any other part of the North Island. This distribution of rainfall is characterised by frequent, lengthy droughts and also by high intensity rainstorms which in the hill country leads to serious erosion. The relationship between rainfall and erosion has been discussed by Grant (1966a). The temporal variability in rainfall is illustrated in Table 24 (New Zealand Meteorological Service 1983a).

Table 24: Extremes in annual rainfall

Climatological Station	Highest Annual Total (mm)	Lowest Annual Total (mm)
Tangoio	2,355	780
Napier Airport	1,336	576

The annual rainfall appears to be generally sufficient for plant growth, it is the monthly distribution and annual variability which lead to soil moisture deficiencies (National Resources Survey 1971). Rainfall has a winter maximum and a spring minimum and is particularly variable in spring-autumn, so that in most years there are periods of drought. At Napier the average duration per drought is 56 days while droughts of up to 150 days have occurred (Grant 1968).

High intensity rainstorms are a feature of the rainfall pattern and may occur in any season. They are usually associated with easterly winds and have produced some of the greatest rainfall intensities recorded in New Zealand. Examples from two climatological stations are given in Table 25 (New Zealand Meteorological Service 1983a).

Table 25: Maximum rainfall intensities

Climatological Station	Maximum 1-Day Rainfall (mm)	Maximum 2-Day Rainfall (mm)
Tangoio	315	472
Napier Airport	297	359

At Rissington in March 1924 512 mm of rain fell in 10 hours, and at Tutira in April 1938 609 mm of rain fell in 3 days (Soil Conservation and Rivers Control Council 1957). Since such high intensity rainstorms contribute significantly to annual rainfall totals and since much of this rain becomes runoff which flows directly into rivers it can be seen that the rainfall available for plant growth is considerably less than that indicated by annual totals.

Summers are very warm and winters are mild with between 40-70 ground frosts per year. The area experiences high sunshine hours and is less windy than areas on the west coast, both features resulting from the protection afforded by the main mountain ranges to the west. Nevertheless wind is not uncommon and is predominantly from the west to south-west. Warm dry winds occur in spring and summer which have a drying effect reducing soil moisture available to plants.

Rock Type

The rock types in this suite are Quaternary in age and are among the youngest in the Region. They consist of Nukumaruan sandstones and siltstones interbedded with limestones and conglomerates (Kingma 1971). The sandstones and siltstones are soft while the limestones and conglomerates are somewhat harder. For this reason the limestones and conglomerates are often prominent, forming outcrops or caps, however in other areas they may be absent. The limestones are shelly and strongly recrystallised (Beu *et al.* 1980). Limestones are more common in the south and east nearer the coast, while conglomerates are more common in the north and west (conglomerates are mapped as gravels on the NZLRI worksheets). These rock types occur throughout the downland and hill country, while terraces are composed of gravels and alluvium.

During the late Pleistocene, at the time of the last glaciation, much of the area was mantled by loess, an aeolian deposit of predominantly silt-sized particles derived largely from sediments from the nearby rivers (Cowie and Milne 1973). Subsequent erosion has removed much of the loess from moderately steep and steep slopes so that today the terraces, downlands and easy hills have a continuous mantle while on the steeper hills it is thin and patchy and in many places absent. On terraces and downlands the loess is more than 1 m thick.

On the NZLRI worksheets loess has been recorded where it is >40 cm thick. Flat to rolling slopes are generally recorded as having a complete cover, and strongly rolling slopes as having a patchy cover. On steeper slopes loess is not recorded although it may be present as a thin and patchy cover.

The area, being on the margin of the tephra deposits from the central North Island, has also had additions of tephra since the last glaciation. Much of the loess has a component of tephra (tephric loess) and pumice may be present in the soil.

Soils

Soils in this suite are predominantly yellow-grey earths and related steepland soils, although in the northern area of the suite some intergrades between yellow-grey earths and yellow-brown earths and related steepland soils are included. The area of the suite is covered by the Mid Hawke's Bay Survey (Pohlen *et al.* 1947), and soils include those from the following soil series: Waipukurau, Poporangi, Matapiro, Crownthorpe, Tangoio and Kidnappers. The soil parent material consists of loess on the easier slopes and sandstones, siltstones, limestones and conglomerates on the steeper slopes. Recent studies suggest that volcanic ash is a more significant component of the parent material of Matapiro soils than was previously recognised (Gibbs 1984).

This suite is defined as being subject to drought, or having insufficient soil moisture for plant growth during part of the year. Annual rainfall is not the best indicator of insufficient soil moisture, especially in central Hawke's Bay where there is a high degree of seasonal variability. Furthermore the effective rainfall available to plants is significantly lower than the total rainfall, due to runoff, evaporation and losses to groundwater. A relationship between yellow-grey earths, intergrades between yellow-grey earths and yellow-brown earths, and rainfall has long been recognised. Traditionally yellow-grey earths have been described as having a well defined dry season and an annual rainfall of <1000 mm distributed over fewer than 150 rain days, while intergrades between yellow-grey earths and yellow-brown earths have an annual rainfall of between 1000-1250 mm and a less pronounced dry season (New Zealand Soil Bureau 1968). Subsequent studies have shown that the soil morphology of these soil groups is related not only to annual rainfall and rainfall distribution but also to the soil moisture status (Bruce 1972, Pohlen 1973, Griffiths 1984). Parfitt and Milne (1984) have noted that yellow-grey earths occur where potential soil water deficits exceed 150 mm in summer and intergrades between yellow-grey earths and yellow-brown earths occur where deficits are less than 150 mm. Given this close relationship between yellow-grey earths, intergrades between yellow-grey earths and yellow-brown earths and soil moisture, the distribution of the LUC suite is better related to the distribution of these soil groups than to mean annual rainfall.

Yellow-grey earths have medium to high natural fertility but are low in phosphorus. Topsoil structure is weak and liable to deteriorate when regularly cultivated. Soils on the easier slopes have compact, heavy subsoils which may be gleyed and mottled. Below about 45 cm from the surface there is a compact horizon (fragipan) which acts as a barrier to percolation. Thus these soils are characteristically dry in summer and wet in winter. The fragipan has widely spaced vertical cracks caused by slow prolonged drying. The surface of the fragipan and these cracks are coated with a thin layer of gleyed soil. This process, known as gammation, is caused by concentration of water above the pan and its slow movement down through the cracks. Intensive subsurface drainage is therefore necessary to reduce winter waterlogging and improve productivity. Irrigation during dry periods is also beneficial but needs to be controlled to prevent further drainage problems.

Intergrades between yellow-grey earths and yellow-brown earths have medium natural fertility. Their topsoils are more strongly developed that those of yellow-grey earths, and they have less well developed fragipans which lead to better drainage characteristics. Steepland soils are shallow and free draining, without the presence of a pan. They are particularly susceptible to drought and erosion.

Topography

Slopes within this suite vary from flat to near vertical. Flat to undulating slopes comprise 3.7% of the suite, 15.9% are rolling to strongly rolling, 53.6% are moderately steep and 26.8% are steep to very steep. Landforms include flat terraces above present river level, downland, hill country, gorges, scarps and coastal cliffs.

There is a trend for relief to increase in a northerly direction. Terraces, downland and easy hill country are predominant in the south, between the Tutaekuri and Ngaruroro Rivers. North of the Tutaekuri River the area is mainly hill country, while further north beyond Tangoio long steep scarps are common. A feature of the terrain throughout the area of the suite is the number of very steep gorges. They are deeply incised into the surrounding terrain, with streams flowing in a south-south-easterly direction.

Erosion

With such a wide range of slopes in this suite a variety of erosion types occur. Provided they are not cultivated there is negligible erosion on slopes less than approximately 20°. However, under cultivation wind, sheet and rill erosion may develop (Figure 64). On slopes greater than approximately 20"soil slip, gully, tunnel gully and sheet erosion occur. As slope increases there is an increase in the incidence of soil slip erosion and a decrease in tunnel gully erosion.

Although flat to strongly rolling slopes are suitable for cropping, little is carried out at present. Erosion is therefore very limited. However with regular cultivation there is a potential for significant erosion, especially on the rolling to strongly rolling slopes. Regular cultivation also leads to significant reductions in soil productivity due to deterioration in soil structure (McQueen 1984).

Guthrie-Smith (1953) described soil slip, tunnel gully and sheet erosion occurring on the hills around Tutira as far back as the 1880s, not long after the land had been cleared of bracken and scrub. Regarding soil slips he wrote *"After a 'southerly buster' or a 'black nor'-easter' of three or four days uninterrupted torrential rain, I have counted on a two-mile stretch of hillside over two hundred slips great and small, new or newly scoured out. Seven or eight times since '82 the grasses and sedges of the valleys around the lake have been overlaid by mud varying in depth from six inches to a couple or three feet".* Severe erosion therefore has been occurring as the result of rainstorms since Europeans first cleared the hills for farming.

As mentioned previously some of the greatest rainfall intensities recorded in New Zealand come from the area covered by this suite. The erosion and flooding that resulted from 3 days of exceptionally heavy rain in April 1938, and which was centered on the Esk catchment, were of such magnitude that they had a strong influence on the passing of the 1941 Soil Conservation and Rivers Control Act (Poole 1983). The effects on the lower Esk Valley are well documented (Soil Conservation and Rivers Control Council 1957, Hill 1938). However only general statements are available about the extent and distribution of the erosion. Some indication of the severity of the erosion can be gauged by the fact that the lower Esk Valley, an area of 708 ha, was silted to an average depth of at least 1 m and depths of 1.8 to 3 m were found over wide areas.

A further consequence of this storm was the establishment of the Tangoio Soil Conservation Reserve. This consisted of 639 ha of steep unstable hill country along an 8 km length of the main highway south of Tutira. The intention was to develop soil conservation techniques and land management practices that would control the erosion and flooding while improving farming productivity. At the same time special attention was paid to protecting the highway. Techniques used included tree planting, intensive subdivision, pasture improvement, application of fertilisers, mob-stocking, fire control and retirement to encourage natural regeneration (Campbell and Anaru 1964). In 1977 the Reserve was transferred from SCRCC to NZFS and became the Tangoio State Forest.

Eyles (1971) in a study of mass movement in the Tangoio Soil Conservation Reserve estimated that from 29 mass movements (mainly soil slips) a total of 9,650 tonnes of material was generated. The soil slips had a mean depth of 0.6 m with the shear planes generally located in a layer of soft silt (loess). The position of the shear planes appeared to relate to the low permeability of underlying beds.

Tunnel gully, although not a major erosion type, is nevertheless characteristic of strongly rolling to moderately steep slopes within the suite. The tunnels or underrunners range in diameter from several centimetres to a metre. Like soil slips they occur in the soft silty layer above a relatively impermeable layer. Water is concentrated above the impermeable layer into channels by irregularities in slope, by soil cracks or by other differences in permeability. This concentration of water scours out the poorly consolidated material, enlarging the tunnel until the roof collapses. Tunnel gully erosion in this suite is characteristic of one of the four tunnel gully environments identified by Lynn and Eyles (1984) in their analysis of tunnel gully distribution and severity within New Zealand.

The low annual rainfall and its high variability is conducive to sheet erosion. During dry periods the condition of the pasture deteriorates. Bare ground is exposed and the soil dries out. Particles are then washed downslope during the next rain. Sheet erosion occurs during rainfalls of much lower intensity than those required to initiate mass movement erosion such as soil slips. Sheet erosion, being less episodic and less spectacular, is a more insidious erosion type. Yet soil loss from sheet erosion may well be as significant or even more so than that from mass movement erosion.

The steeper hills are also occasionally subject to large-scale collapses. These usually involve large blocks of limestone from caps or beds which have been undermined by the erosion of the less resistant surrounding rocks. Such limestone blocks are a feature in some areas where they have come to rest on colluvial footslopes or in stream beds. Lake Tutira was formed by the collapse of part of a hillside which blocked the outlet to the valley. At the time of European settlement the vegetation of the catchment was largely bracken fern and scrub, the original forest having been destroyed by repeated fires. Farming began in 1873, and with it an increase in erosion and runoff. The lake has since acted as a large sediment trap. Two bathymetric surveys have been conducted of the lake (Grant 1966b). The first was carried out in 1925 by Guthrie-Smith, the owner of Tutira Station, and the second in 1963 by Grant. A comparison of results show that the lake bottom has been raised by 1.1 m in the 38 year period. This represents an input of 1.9 million $m^3$of sediment from the catchment. Not all sediment however will reach the lake, much accumulates on colluvial footslopes or broad valley bottoms. (Only part of the catchment comprises LUC units from this suite, but it is from these LUC units that much of the sediment is derived.)

The lake is now in an advanced state of eutrophication (Teirney 1980). The problem became apparent in the late 1950s, less than 10 years after the commencement of aerial topdressing using phosphate fertilisers. Studies have now shown that soil erosion and surface runoff of fertilisers, dung and urine are major causes of the eutrophication. It is possible therefore to use the lake as an indicator of both the sediment and runoff that come from the surrounding hills.

Vegetation

Pasture is the dominant vegetation throughout the suite, except in gorges where mixed indigenous scrub and manuka dominate, and coastal cliffs where scattered tauhinu occurs. On terraces and downland the pasture is high producing with small areas of root and green fodder crops and cereals. On the hills the pasture is low producing and manuka occurs, both scattered and in small blocks. On the steeper hills there is an increase in manuka and there is also some mixed indigenous scrub. On the terraces, downland and easier hills in the drier south-eastern area of the suite the pasture is conspicuously clear of weeds, rushes and scrub. Since the NZLRI worksheets were printed a significant area of the hills in the Esk-Tangoio district have been planted in exotic forest.

Land Use and Land Management

Sheep and cattle farming is by far the major land use within the suite. In the south farming is intensive while in the north it is largely extensive. Because of the dry climate there is little scrub reversion, except in the Tangoio-Tutira district where rainfall is higher and slopes are steeper. On the steeper more erodible hills soil conservation measures are necessary, principally tree planting.

A little cropping is carried out on the downlands, although this is limited to root and green fodder crops and cereals as part of normal farming practice. Without irrigation other crops would be restricted because of the long dry spells during summer.

As has already been discussed the hill country areas of this suite are subject to repeated erosion-producing storms. Despite the presence of a demonstration farm (part of the Tangoio Soil Conservation Reserve) managed for the purpose of promoting soil conservation techniques, and especially the benefit of tree planting, few such techniques have been adopted. It is perhaps ironic therefore that a recent development has been the move to production forestry on the hills in the Esk Valley-Tangoio district in response to the construction of a pulp and saw mill at Whirinaki near the mouth of the Esk River. Economic considerations have resulted in far better protection from erosion for the hills than was achieved in thirty years of promoting soil conservation.

Land Use Capability Units

There are 9 LUC units in this suite, ranging from class III to class VIII. There are 3 arable units; 4 are hill country units and 2 units are non-productive. Production potential is medium to high. Summer droughts are a limitation to production for all units, while erosion is the major limitation on steeper hill country.

Table 26 lists the potential stock carrying capacity and the site index for *P. radiata* for the LUC units in the suite. The potential stock carrying capacity figures show a steady decrease from IIIsl to VIIe3. (IIIsl has a slightly lower figure than Illel mainly because of poorer drainage.) The site index figures show the same trend, although not to the same extent; flat to rolling downlands have the same site index, hill country a slightly lower figure and scarps and gorges the lowest figure. These trends in production values relate to inreasing slope and shallowness of soil and the associated increasing effects of erosion. The relationship between LUC units is illustrated in Figure 61.

Table 26: Potential production data for LUC units on landforms with a mantle of loess

LUC Unit	Potential Stock Carrying Capacity (su/ha)	Site Index for *Pinus radiata* (m)
IIIsl	20	27-32
Illel	22	27-32
IVel	22	27-32
Vcl	20	27-31
VIe2	17	27-31
VIe5	17	27-31
VIIe3	14	25-30
VIIIe2	—	—
VIIIe3	—	—

LUC unit **IIIsl** (2,560 **ha)—**Figure 62

This unit is mapped on the flat to undulating medium height terraces found in the narrow valleys in the hill country between the Ngaruroro and Tutaekuri Rivers. The terraces are comprised of Upper Pleistocene gravels, silts and sands overlain by loess. The soils developed from these parent materials are Waipukurau sandy loam and Poporangi sandy loam. Both soil types are light textured and have high natural fertility. Both have subsoil pans which impede drainage, Poporangi sandy loam being the more poorly drained of the two. Limitations to cropping imposed by the soil structure, together with the presence of a subsoil pan are the major limitations to use. Summer droughts also impose a limitation. Drainage is required to lower the perched water table in winter and irrigation would be of value for cropping. The light soils are susceptible to slight wind erosion when cultivated. The unit is intensively grazed and has a potential for cereal cropping. Potential stock carrying capacity is 20 su/ha and site index for *P. radiata* is 27-32 m.

LUC **unit Illel (2,640 ha)—**Figure 62

On rolling to undulating downland loess mantles Pleistocene sandstones and siltstones which are interbedded in places with limestones and conglomerates. Soils belong to the Matapiro series, the main type being Matapiro sandy loam. They have compact subsoils and pans, but although drainage is slow they are not as poorly drained as the soils of IIIsl. Again summer soil moisture deficiencies are a limitation to plant growth, however due to the sloping nature of the unit erosion is the main limitation under cultivation. These areas are therefore mapped as Illel. There is a potential on these sandy soils for slight to moderate sheet, rill and wind erosion, requiring contour cultivation and the provision of shelterbelts. This unit like IIIsl is suited to cereal cropping, although at present land use is almost entirely intensive grazing. The potential stock carrying capacity, at 22 su/ha, is slightly higher than on IIIsl because of somewhat better drainage. Site index for *P. radiatah* however the same.

LUC **unit IVel (7,470 ha)—**Figure 62

As slopes become steeper the potential for erosion under cultivation increases. On rolling to strongly rolling downland, which is the limit for cultivation, there is the potential for severe sheet and rill erosion and for moderate wind erosion. These areas are mapped as IVel. The soils are the same as those of Illel, however cropping would be mainly limited to occasional root and green fodder crops. At present land use is intensive grazing. Both Illel and IVel occur mainly in the Matapiro-Sherenden district. On all three arable LUC units in the suite erosion is negligible under pasture. Production potentials are the same as for Illel.

LUC **unit Vcl (3,800 ha)—**Figure 63

Areas of hill country between the Ngaruroro and Tutaekuri Rivers, where limestone and conglomerate beds are common, are often very stable, showing no signs of past or present soil slip erosion. These areas are mapped as Vcl, the strongly rolling to moderately steep hills being too steep for cultivation and having only a slight sheet erosion potential. The loess mantle is thinner than in the previous three LUC units, and is patchy where slopes are moderately steep. Matapiro sandy loam is the major soil type with Crownthorpe sandy loam on the steeper slopes. Although the soils have compact subsoils and in some places pans, drainage is good due to the steepness of the LUC unit. The limestone beds add to the natural fertility, which is fairly high. The major limitation to use therefore is the presence of summer droughts. The rainfall ranges from 800 mm p.a. at Napier and near the Ngaruroro River to 1000 mm p.a. near Sherenden and Whanawhana. Droughts of up to 3 or 4 months are common in summer with pasture growth being severely restricted. The unit is used for intensive grazing, with a feature for hill country being the high producing pasture together with the absence of scrub and weeds.

Potential stock carrying capacity is high for hill country at 20 su/ha, and site index for *P. radiata* is medium to high at 27-31 m.

LUC **units VIe2 (13,090 ha)—**Figures 13, 14, 64 and **VIe5 (37,330 ha)—**Figures 15, 62, 65

VIe2 is similar to Vcl except that here erosion is a continuing problem. Slopes are usually short and there is either present erosion in the form of soil slips or tunnel gullies, or evidence of past erosion. Old slip scars although regrassed can still be seen and the slopes often have a hummocky surface. The erosion potential is for slight soil slip, sheet and tunnel gully. However because the erosion potential is only slight and because of the presence of summer droughts this LUC unit would be better reclassified as Vic.

VIe5 is mapped as slopes become steeper and erosion potential increases. The slopes are moderately steep to steep and longer than those of VIe2. Erosion is more common with a potential for moderate soil slip and slight sheet, gully and tunnel gully. Soils belong to the Crownthorpe series with Tangoio series on the steeper slopes. In the Tangoio district the less steep slopes have a shallow layer of tephra overlying the loess and various rock types. The soils are composite yellow-brown pumice soils on yellow-grey earths and belong to the Rissington series (Rijkse 1980).

The two units occur throughout the area of the suite although Vie 5 is more common in the north in the Tangoio-Tutira district. Here annual rainfalls are higher (1200-1400 mm p.a.), and this is reflected in the erosion history of the district. Planting of conservation trees is recommended, particualrly in the case of VIe5. Intensive grazing is the major land use of both units, and they are also the units on which *Pinus radiata* is being planted.

Production potentials are the same for both LUC units. Site index figures for *P. radiata* are the same as for Vcl, while potential stock carrying capacity has dropped 3 su/ha to 17 su/ha.

LUC **unit VIIe3 (16,290** ha)—Figure 66

Where slopes are steep to very steep the potential for soil slip erosion is severe to very severe. Because of this erosion potential these areas are mapped as VIIe3. There is also a potential for moderate sheet erosion and slight gully and tunnel gully erosion. Slopes are long, often with prominent beds of limestone or conglomerate outcropping. They occur as gorges, formed by downcutting of a series of rivers as they flow in a south-easterly direction towards Hawke Bay, or as scarps, particularly in the Tangoio district.

On such steep slopes loess is either very thin or absent, especially where erosion has taken place. The steepland soils are typically those of the Kidnappers or Tangoio series, developed on mudstone or sandstone respectively. The most common soil type is Kidnappers silt loam. In the north-western area of the suite rainfalls may be as high as 1400 mm p.a. and here soils are those of the Mokamoka series and are steepland soils related to yellow-brown earths. Areas of bare rock are common, and sometimes blocks of limestone or conglomerate are found on the colluvial footslopes.

The vegetation consists of low producing pasture and scrub. The unit is presently used for grazing, where there is a potential stock carrying capacity of 14 su/ha. There is a small amount of production forestry in the Tangoio district. Site index for *P. radiata* is 25-30 m. The greater use of trees, either open planted to supplement pastoral farming or as erosion control forestry is necessary, both to control erosion and enhance production.

LUC **units VIIIe2 (2,700** ha) and **VIIIe3 (470** ha)—Figure 67

VIIIe2 is mapped where gorges and scarps are oversteepened and have slopes greater than 35°. Here the slopes are too steep and the soils too shallow for productive use. The potential for soil slip erosion is still very severe, while there is also a potential for moderate sheet and gully erosion. Soils and rock types are the same as for VIIe3. Mixed indigenous scrub is the major vegetation and this should be encouraged to regenerate to help conserve the soil and slow down runoff rates.

In the Tangoio district the hills terminate at the coast in a series of cliffs between 150-300 m high. They are mapped as VIIIe3 and have been included in this suite because they have a common rock type. The cliffs are near vertical with mainly bare rock and a little tauhinu scrub. There is some rock fall and sheet erosion but no significant retreat of the cliff face, although during the Hawke's Bay earthquake of 1931 there was collapse of a large cliff south of the Waikari River mouth. Coastal cliffs also occur near Mohaka, on Mahia Peninsula and between Mahia Peninsula and the Gisborne Plains, and they are included in the appropriate suites. The total area of coastal cliffs in the Northern Hawke's Bay Region is 1,300 ha.

	IIIsl	IIIel	IVel
Slope		4-15°	8-20°
Erosion Potential	1 w (when cultivated)	1-2Sh, 1-2R, 1-2W (when cultivated)	3Sh, 3R, 2 W (when cultivated)
	Vc1	VIe2	VIe5
Slope	21-25°	. 16-25°	21-35°
Erosion Potential	1Sh	1sSl, 1Sh	2sSi, 1Sh, 1G, 1T
	VIIe3	VIIIe2	VIIIe3
Slope	>2 6°	>3 5°	>3 5°
Erosion Potential	3~4sSS, 2Sh, 1G, 1T	4sSl, 2Sh, 2G	2-3sSL 2Sh, 2G

Figure 61: Relationship between LUC units on landforms with a mantle of loess.

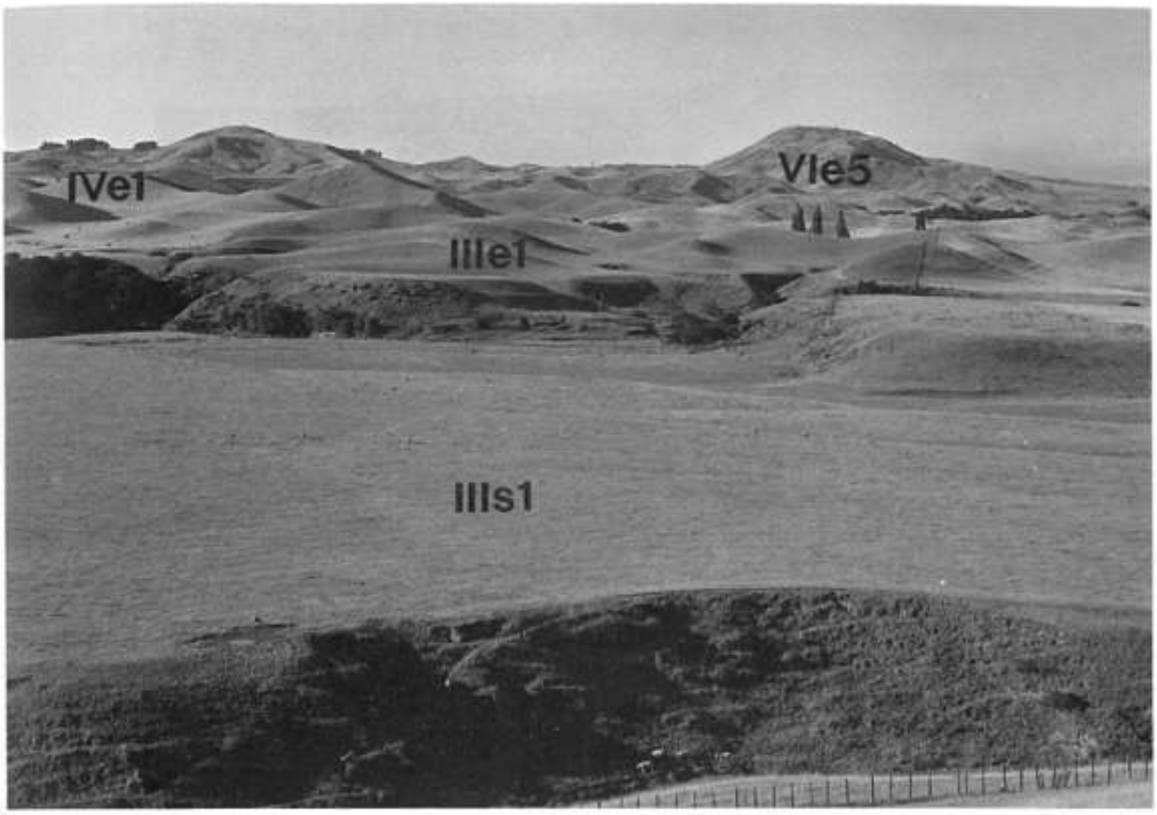


Figure 62: IIIs1. Crownthorpe Road. N134/094330, looking north. IIIe1, IVe1 and VIe5 in background.

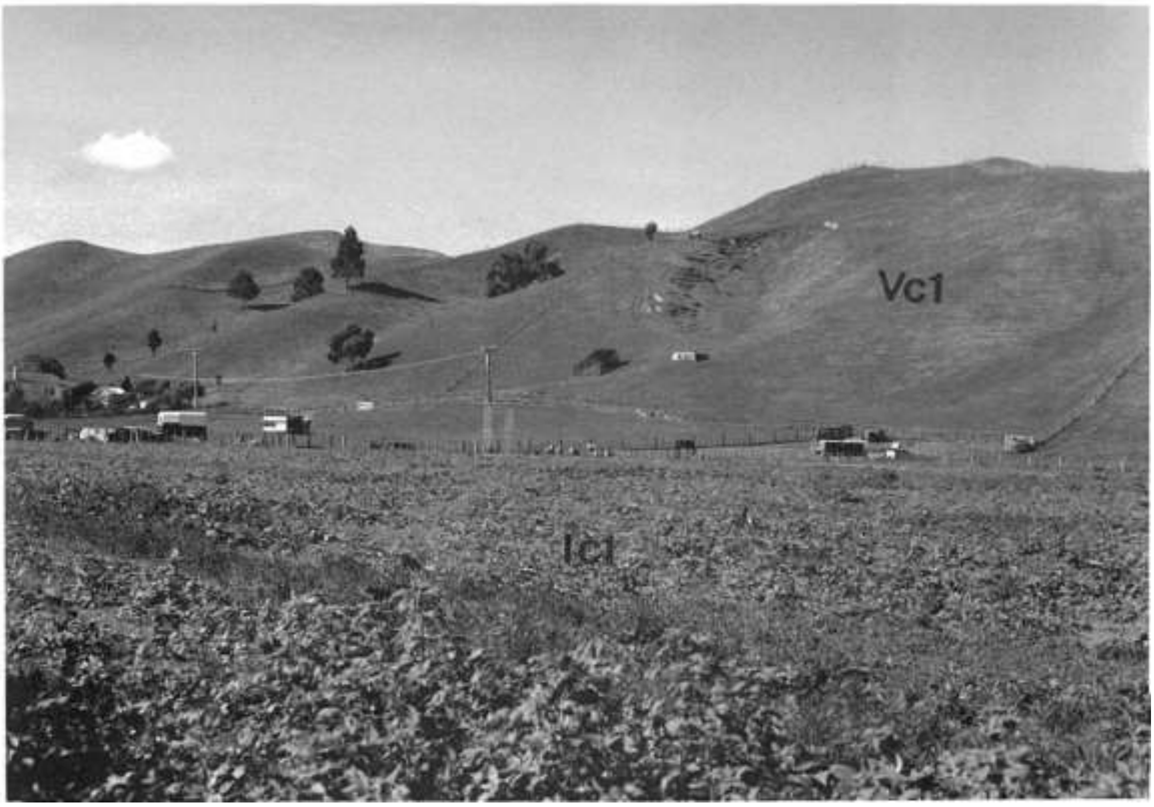


Figure 63: Vcl. Moteo Road, west of Taradale. N134/208352, looking north-east. Icl in foreground (LUC suite 1).

Figure 64: VIe2. Esk Valley. Rill and sheet erosion on recently cultivated slopes. N124. Photo: J R Fletcher

Figure 65: VIe5. Tangoio Road. N124/333627, looking south-east.

Figure 66: VIIe3. Darkys Spur, north-west of Tangoio. N124/255692, looking east.

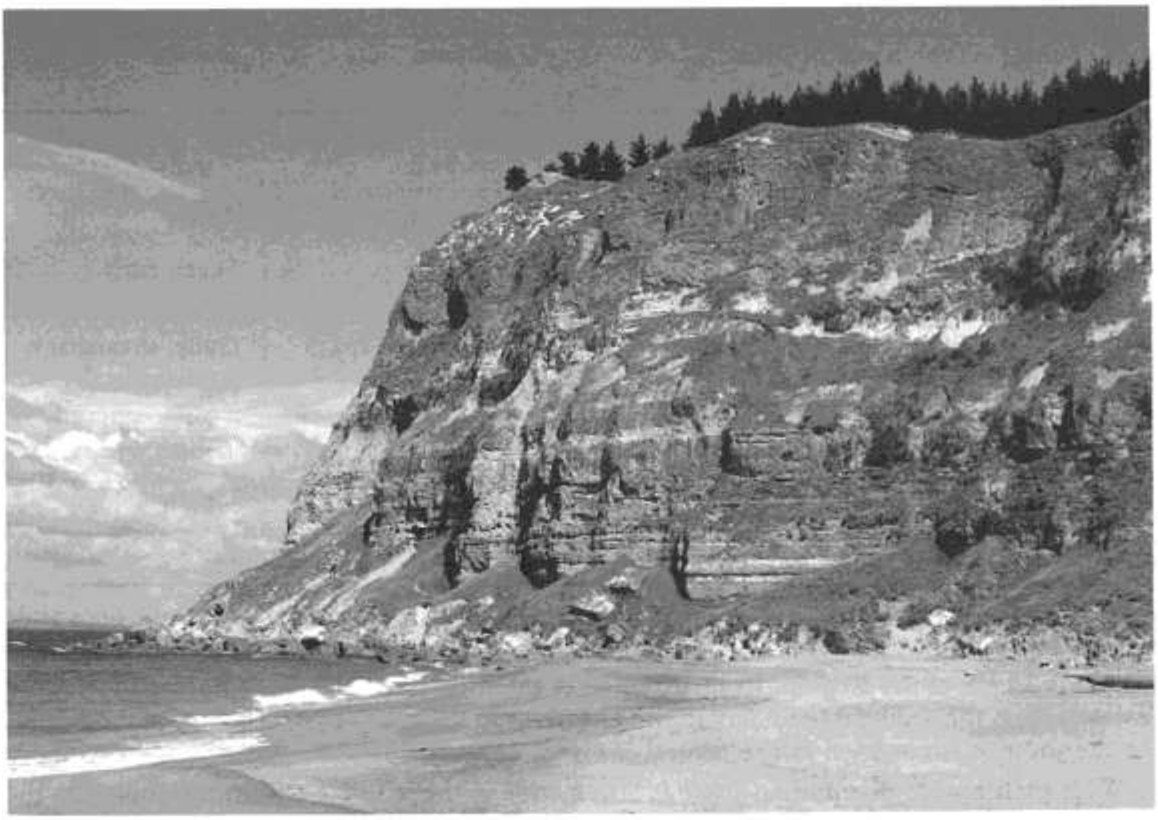


Figure 67: VIIIe3. Waipatiki Beach, east of Tangoio. N125/391618, looking south-west.

LUC SUITE 11: LANDFORMS WITH A MANTLE OF TAUPO AIRFALL TEPHRA

The Northern Hawke's Bay Region has been mantled by a series of tephras from the Taupo, Okataina and Tongariro Volcanic Centres (Pullar and Birrell 1973). Over much of the Region the thickness of this mantle is sufficient to at least partially mask the properties of the underlying bedrock.

This series of tephras is given in Table 4. Not all the tephras in this sequence are necessarily present in all locations. In some places a tephra may be absent because of erosion subsequent to deposition. Other areas may be beyond the range of a particular tephra. However three major tephras or tephra combinations are normally present. The uppermost is Taupo Pumice Formation (recorded as Kt where thickness is >40 cm) consisting mainly of two members: Upper Taupo Pumice and Taupo Lapilli. This overlies Waimihia Formation consisting of two members: Waimihia Ash and Waimihia Lapilli. The lower lapilli layer is usually the more significant, (recorded as Lp along with Taupo Lapilli where thickness is >60 cm). Beneath Waimihia Lapilli is a series of older, more weathered, compact tephras which, because of their characteristics in relation to land use, have been grouped together (recorded as Mo where thickness is >40 cm). The most significant of these are Rotoma Ash and Waiohau Ash in northern and central areas and Tongariro Ash in southern areas.

Tephra is the soil parent material for more than 60% of the Region. Where this is the case 6 LUC suites have been defined (Table 27), based on the type and thickness of these tephras.

The largest of these suites and in fact the largest in the Region is a suite of 13 LUC units where Tertiary and Quaternary mudstones and sandstones have been mantled by a series of these tephras, the uppermost of which is Taupo airfall tephra[1].

The soils that have developed on these tephras, and that are characteristic of this suite, are yellow-brown pumice soils and podzolised yellow-brown pumice soils.

Table 27: LUC suites on tephra

LUC Suite Number	Tephra and Bedrock	Landform	Erosion
11	Taupo airfall tephra on shallow Waimihia Lapilli on older ashes on mudstone or sandstone	Terraces, downs, hills, scarps & mountainlands	Soil slip, tunnel gully, debris avalanche, sheet
12	Shallow Waimihia Lapilli on older ashes and loess	Raised marine terraces	Wind
13	Taupo airfall tephra on thick coarse Waimihia Lapilli on older ashes on greywacke or ignimbrite	Low hills	Sheet, gully
14	Taupo flow tephra and water-sorted tephra	River teraces and plains	Gully, streambank, wind, sheet
15	Taupo airfall tephra on shallow Waimihia Lapilli on older ashes on greywacke	Hills and mountainlands	Debris avalanche, scree, soil slip, sheet
16	Taupo airfall tephra on shallow	Upland plateaux and	Wind, sheet, scree,

Within this suite the 13 LUC units range from class III to class VIII and occur on a wide range of landforms from flat teraces to very steep mountainlands. The suite covers 380,850 ha which is 33.1% of the Region. Its distribution is extensive, particularly in the north where it extends from the regional boundary in the Ureweras to near the coast at Wairoa and Nuhaka. In the south it is confined to the central lowlands (Figure 68).

With such a wide distribution there is also a wide climatic range within the suite. On the basis of this climatic range the suite can be divided into 2 "subsuites":

a. Lowland subsuite

b. Upland subsuite.

[1] Except in the north-west of the Region, where a thin layer (5-10 cm) of Kaharoa Ash is present.

The lowland subsuite contains 5 LUC units which occur at lower altitudes (<600 m) in central and eastern areas where temperatures are warmer and rainfall is below approximately 2000 mm p.a. The upland subsuite contains 8 LUC units at higher altitudes (>600 m) in the north and west where temperatures are cooler and rainfall is above approximately 2000 mm p.a. In the upland subsuite the tephra mantle is thicker (nearer to source) and leaching has led to podzolised soils. The climate also has a pronounced effect on the vegetation pattern, with a gradient from pasture to indigenous forest as rainfall increases.

There are therefore a number of patterns or trends which can be traced inland from east to west. These can be summarised as:

(i) increase in altitude
(ii) increase in rainfall
(iii) decrease in temperature
(iv) increase in slope angle
(v) increase in thickness of tephra
(vi) increase in leaching
(vii) increase in erosion potential and, as a result of the above trends, there is a corresponding:-
(viii) decrease in land use capability.

A wide range of erosion types occur within the suite, dependant on the slope, thickness of tephra and vegetation. When cultivated or otherwise exposed, soils are prone to wind, sheet and rill erosion. On hill slopes soil slip is the characteristic erosion type, with tunnel gully occurring where significant thicknesses of lapilli are present. On steep forested slopes the major erosion type is debris avalanche.

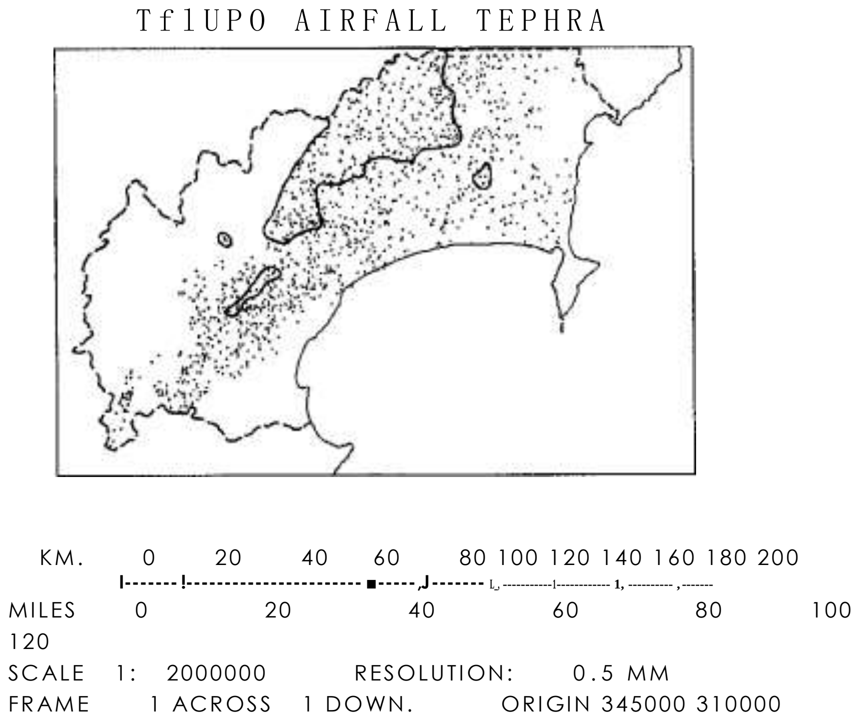


Figure 68: Location of LUC suite on landforms with a mantle of Taupo airfall tephra (upland subsuite within solid line).

Climate

There is a wide range of climatic conditions within this suite and in some cases it is this variation in climate that is the basis for LUC definition. Most climatic conditions experienced within the Region occur within this suite, from a mild coastal climate where droughts may occur, to a cold montane climate with high annual rainfall. Only the low rainfall and drought-prone conditions experienced in the south-east of the Region are not found in the suite.

The rainfall is between 1000 and 3500+ mm p.a. although, as is the case throughout the east coast, there is a high variability between annual totals. High intensity rainstorms are also a feature of rainfall distribution.

Sixty eight percent of the suite has a mild lowland climate (lowland subsuite) and 32% has a cool, wet, montane climate (upland subsuite). In the upland subsuite frosts are common and occasional snow falls may occur. A climatological station at Onepoto, Lake Waikaremoana, on the boundary between the two subsuites records the following climatic information:

Mean annual rainfall	2062 mm
Highest annual rainfall	3017 mm
Lowest annual rainfall	1394 mm
Raindays per annum	166
Mean annual temperature	11.6°C
Frost days per annum (ground frost)	38
Snow days per annum	4.

Rock Type

The cover deposit which characterises this LUC suite is airfall tephra of the Taupo Pumice Formation (Froggatt 1981). Except in the north-west around Lake Waikaremoana it is the uppermost deposit. North of Lake Waikaremoana 5-10 cm of Kaharoa Ash, dating from approximately 900 years BP (Healy *et al.* 1964), overlies Taupo airfall tephra. In this location Kaharoa Ash is a fine, loose, white pumice ash.

Taupo Pumice (1800 years BP) occurs throughout the suite and varies in thickness from approximately 60 cm in the north-west to 15 cm at the coast. Of the two main members of Taupo Pumice Formation (Healy *et al.* 1964) found in the Region, the underlying Taupo Lapilli is up to three times the thickness of the Upper Taupo Pumice. The appearance of Upper Taupo Pumice is a black sandy loam with a few pale yellow, soft lapilli, highly vesicular and fibrous. Taupo Lapilli consists of pale yellow to strong brown, coarse, uneven-sized, soft lapilli, highly vesicular and fibrous (Rijkse 1974d).

Beneath Taupo Lapilli is a distinctive layer of strong brown to yellow, loose, coarse, uniform lapilli. This layer, which in central areas contains a band of dark, vesicular rhyolite, is termed Waimihia Lapilli (Healy *et al.* 1964). Waimihia Ash, a layer of fine brown ash, occurs in some areas overlying this lapilli layer. Together this ash and lapilli layer constitute the Waimihia Formation, dating from approximately 3400 years BP. Waimihia Lapili is found throughout the suite and is thickest in the centre of the Region where between 80 cm-1 m is found in the west and 30 cm at the coast near Raupunga (Walker 1981).

In northern and central areas of the suite a number of weathered rhyolitic tephras and loess deposits occur beneath the Waimihia Formation. These are tephras of the Rotorua Sub-group and are not readily distinguishable in the field by appearance. They form a weathered, compact, brown layer of fine ash and consist mainly of Rotoma Ash (7,300 years BP) and Waiohau Ash (11,200 years BP).

In southern areas of the suite the deposits beneath Waimihia Lapilli are Tongariro Sub-group tephras, collectively known as "Tongariro Ash" (Pullar *et al.* 1973) and mapped in more detail by Topping (1973). "Tongariro Ash" is andesitic and consists of a number of dark brown, weathered, compact tephras. This layer is approximately 50 cm thick in the Puketitiri district, thinning to only a trace at the coast.

A number of older tephras and loess layers have been identified beneath the previously mentioned tephras, although these are usually only present on stable (usually flat) sites. These tephras include Oruanui Ash [now known as Kawakawa Tephra Formation (Vucetich and Howorth 1976)], Mangaoni Lapilli and Rotoehu Ash.

Knowledge of the sequence, age and distribution of tephras in Northern Hawke's Bay is still being refined. Much of the existing literature deals with the deposits much closer to source. However several recent studies in the Region have centred on swamps and lakes, which provide ideal sites for tephra preservation. These include the Kaipo Lagoon peat bog in the Urewera National Park (Lowe and Hogg 1986) and lake sediments at Tiniroto (Kohn *et al.* 1981).

In this suite the basement rocks underlying these tephras are mudstones, siltstones, sandstones and limestones of Quaternary and Tertiary age. These rocks may be bedded, jointed or massive. Differences in properties between the rock types are masked by the thickness of the tephra mantle. Only where the underlying rock (mainly mudstone) is physically weakened by crushing and/or faulting, leading to deep-seated earthflow, gully and slump erosion, does rock type have an effect at the surface. These areas are then mapped within LUC suite 5.

In the east of the Region and on steep slopes where this tephra mantle becomes shallow or is absent the suites mapped are based on the underlying bedrock.

Soils

The soils developed on these tephras are yellow-brown pumice soils, and their physical properties reflect this tephric origin. Topsoils are very friable with weakly developed structure and subsoils are loose and coarse-textured. Soils are therefore well drained yet retain sufficient moisture for plant growth. They are deficient in plant nutrients but respond well to fertilisers. In addition, in upland areas with cool temperatures and high rainfall, leaching of nutrients has led to the accumulation of iron in the subsoil, further adding to the low nutrient status of the soils. Such soils are regarded as podzolised yellow-brown pumice soils, and are moderately podzolised where iron bands are discontinuous and strongly podzolised where iron bands are continuous.

Yellow-brown pumice soils are subdivided according to the kind and thickness of the tephra beds from which they are derived. A number of soil series are mapped within this suite reflecting these differences. In the following example soil series from the Wairoa County Survey (Rijkse, unpublished), are mapped from the coast inland in the following order: Gisborne, Tiniroto, Tuai, Ruakituri and Matawai series. These series grade into one another and reflect an increase in the thickness and the coarse-textured nature of the tephra from the Gisborne to the Matawai series. Also with distance inland there is inreasing rainfall and altitude leading to increased leaching.

Soils in this suite are mapped using five soil surveys. The Wairoa County Survey (Rijkse unpublished) is the main survey, covering 56.2% of the suite. The Mid hawke's Bay Survey (Pohlen *et al.* 1947) covers 23.4% of the suite, 18.4% is covered by the General Survey (New Zealand Soil Bureau 1954), 1.7% by the Rangitikei County Survey (Campbell 1979) and 0.3% by the Taupo County Survey (Rijkse in prep.).

An outline of the characteristics of yellow-brown pumice soils and podzolised yellow-brown pumice soils in the Northern Hawke's Bay Region is given by Rijkse (1974a, b, c, d).

Topography

Topography within the suite is varied, with slopes ranging from flat to very steep. Flat to undulating slopes comprise 5.8% of the suite, 31.4% are rolling to strongly rolling, 47.9% are moderately steep and 14.9% are steep to very steep. Apart from the steepest slopes which are found in the west there is little pattern in slope distribution.

There is a wide range of landforms within the suite. While hill country is the major landform others include flat terraces above present river level, downland, upland plateaux, scarps and mountainland.

Erosion

The presence of a largely intact tephra mantle, consisting of a number of deposits ranging from 1800-11,200 years BP, indicates that erosion rates in the past have been low and that the suite, except in the case of steep mountain slopes, consists of generally stable landforms. Even on hill country landforms the number of old erosion scars is small. Nevertheless a number of different erosion types occur throughout the suite and these are largely related to slope angle.

Soil slip and tunnel gully are the most common erosion types. The critical angle for soil slip development would appear to be 18°, while tunnel gullies may form on slope angles as low as 8°(Harmsworth *et al.* 1987).

Soil slips do not normally expose bedrock, the slip plane forming at the base of the tephra mantle or within the underlying regolith (weathered rock) zone. The depth of soil slip scars therefore is related to the thickness of tephra and varies from 0.5-1.5 m. Whether debris from soil slips reaches streams is dependent upon the position on slope of the slip scars. Approximately 50% of the total debris produced by soil slips reaches streams.

The presence of tunnel gully erosion is related to the thickness of lapilli and therefore is commonest in central areas of the suite. Here Waimihia Lapilli is particularly thick (up to 1 m) and overlies a more compact and therefore less permeable layer. Water infiltrates readily though the porous lapilli as far as the compact layer (either tephra or weathered bedrock). It then flows along this contact to be concentrated into channels by subsurface irregularities. The concentration of water then scours out the loose lapilli to form a tunnel, the roof of which eventually collapses to produce openings at the ground surface (Figure 82). Normally a number of such openings appear in a line down a slope, indicating the direction of the tunnel. Ultimately collapse of the roof is so complete that these openings coalesce to produce a gully, however this situation is not common in the Region. The incidence of tunnel gully erosion decreases as the thickness of tephra decreases with increasing slope. Tunnel gullies are rare on slopes greater than 30°.

On steep forested slopes debris avalanches are characteristic. Here scars expose bedrock. Material from the initial failure continues to scour the length of the slope, removing vegetation, soil and regolith, until it reaches the base of the slope where debris enters a stream.

Because of the light-textured, very friable nature of the soils they are susceptible to wind, sheet and rill erosion. Such erosion may develop along fence lines or farm tracks or in other situations where removal of vegetation exposes the soil, such as 'root raking' during development of pasture from scrub. In some areas stock camping also exposes the soil to wind and sheet erosion. However it is those areas with a potential for cropping which are the most susceptible to wind, sheet and rill erosion, although at present little cropping is carried out.

In areas underlain by alternating sequences of rocks, (mainly mudstones and sandstones) small-scale failures along bedding planes are common. Where such areas are stable they are mapped within this suite. However where areas are experiencing deep-seated earthflow, slump and gully erosion, or where stable areas still have a potential for such erosion, they are mapped within LUC suite 5.

A number of lakes have been formed by large-scale collapses of the surrounding terrain, most famous of which is Lake Waikaremoana (Marshall 1926, Ongley 1932). Others include Lakes Rotongaio, Rotoroa and Rotonuiaha at Putere, Lake Opouahi and the series of lakes at Tiniroto. In the case of Lake Waikaremoana (and some of the other lakes) the surrounding hills consist of alternating sequences of mudstone and sandstone which dip to the south or south-east. Again the bedded nature of these rocks would have facilitated the collapse, which was possibly earthquake-triggered.

These lakes are prehistoric features, indicated by the presence of a tephra mantle overlying the debris which led to their formation, and also by radiocarbon dating of standing submerged trees or logs at the base of lake sediments. In the case of Lake Waikaremoana the presence of Waimihia Lapilli on the slip debris and in the lake bed gives a minimum age of 3400 years BP for its formation. Wood from the drowned forest still standing on the lake bed gives a radiocarbon date of approximately 2,200 years BP.

A more recent example of lake formation was during the 1931 Hawke's Bay earthquake when Lake Ngatapa was formed as a result of a landslide which dammed the Te Hoe River nears its junction with the Mohaka River (Adams 1981). This lake, 2 km long and 25 m deep, disappeared however during the April 1938 storm. There is also evidence of the Mohaka River being dammed below Willowflat by a prehistoric slump.

Vegetation

There is a gradient inland with increasing altitude and rainfall from pasture to scrub to indigenous forest. This sequence from modified to unmodified vegetation is highlighted in the two subsuites.

In the lowland suite the vegetation consists mainly of pasture which in inland areas is associated with increasing amounts of manuka, fern and mixed indigenous scrub. Also significant areas of exotic forest occur in this subsuite.

In the upland subsuite the vegetation is almost entirely indigenous forest. The distribution of these forests is altitudinally controlled, from small areas of lowland podocarp-hardwood forest on the margins of the subsuite to podocarp-hardwood-beech and the more common beech forest at higher altitudes. The beech forests are dominated by red and silver beech but include small areas of mountain beech and stunted silver beech at the highest altitudes. A detailed description of these forests is given by McKelvey (1973).

Most of the forest outside the Urewera National Park has been logged and helicopter logging is presently being carried out near the Park boundary, notably in the Maungataniwha district.

Land Use and Land Management

Land use is varied and includes cropping, pastoral farming, exotic forestry, indigenous forestry and recreation. Of these pastoral farming is the major use, occupying approximately 60% of the suite. This suite also contains the largest area of undeveloped hill country in the Region. At the time of this survey there were approximately 50,000 ha of scrubland scattered throughout the hill country, mainly on class VI land. In addition significant areas of grassland have a scrub component, either scattered or in remnant clumps confined to gullies or steep faces. Although this figure will have been reduced during the intervening period, significant areas still exist. This situation reflects the earlier history of this suite.

Prior to the widespread use of fertilisers and the recognition of trace element deficiencies in pumice soils, farming of land within this suite met with only limited success. Low fertility soils and vigorous scrub reversion meant that much of this land remained idle until the late 1940s. Redevelopment of much of this land was undertaken by the Department of Lands and Survey by the establishment of farm settlement blocks.

Another consequence of this land proving difficult for farming was the establishment of a number of exotic forests. These are confined to mainly class VI hill country in the lowland subsuite. Patunamu State Forest was established in 1949, followed by Mohaka State Forest in 1958 and Wharerata State Forest in 1959. Other State Forests located at least partially within this suite are Esk, Woodstock and Raupunga. Private sector forestry is increasing, with significant company owned forests at Willow-flat, Maungataniwha and Waikoau.

The majority of the upland subsuite, with even greater limitations to development, is still in indigenous forest. Such areas are either in the Urewera National Park or a number of nearby State Forests. A general account of the Urewera National Park is given by the Urewera National Park Board (1968). A few small areas of privately owned indigenous forest border these crownlands and most have been or are presently being logged. In addition to recreation these forests perform an important soil conservation and water management function.

Finally some maize and root and green fodder crops are grown on the terraces bordering the lower reaches of the major rivers such as the Mohaka, Waikari and Waihua.

Land Use Capability Units

As previously mentioned the 13 LUC units in this suite are divided into two subsuites, the lowland and upland subsuites, on the basis of climate and altitude.

The LUC units in the upland subsuite are generally of lower capability than those in the lowland subsuite. In addition to a climatic limitation, soils are more podzolised, leading to lower productivity, and erosion potential is greater.

The lowland subsuite contains 5 LUC units, defined on increasing slope from class III to class VI. Climate conditions are generally favourable. In the upland subsuite there are 8 LUC units, with increasing erosion and climatic limitations from class IV to class VIII. The relationship between LUC units is illustrated in Figures 69a, b, c.

The physical differences between the two subsuites mean that flat to undulating slopes that are mapped as class III in the lowland subsuite are class IV in the upland subsuite. Similar reductions in capability also occur between the subsuites on steeper slopes.

As stated in the description of erosion the presence of a largely intact tephra mantle indicates past stability, particularly in classes III-VI. However the change from forest to grassland which has occured within the last 100 years does not guarantee this situation will continue. For this reason erosion is still seen as the main limitation on most of the LUC units. Notwith-standing this, recent studies (Harmsworth *et al.* 1987) indicate that for strongly rolling to moderately steep slopes, in both the lowland and upland subsuites, erosion may not be the major limitation, as was previously identified (see LUC units VIel and VIell).

Table 28 lists the LUC units in the suite in decreasing capability order, together with the present and potential stock carrying capacity and the site index for *Pinus radiata.* These production figures show a general decrease with decreasing capability. There are also potentially large increases between present and potential stock carrying capacities, particularly for LUC units of higher capability.

Table 28: Production data for LUC units on landforms with a mantle of Taupo airfall tephra

LUC Unit	Stock Carrying Capacity (su/ha) Present Average	Attainable Potential	Site Index for *P. radiata*
IIIs3	10	15	33-35
IIIe3	10	20	32-34
IVe2	10	20	28-33
IVcl	_	10	23-28
VIel	10	20	30-33
VIe6	9	17	30-33
VIell	7	11	22-29
VIc3	6	12	Unsuitable
VIIeH	3	4	20-29
VIIIe2	Unsuitable	Unsuitable	Unsuitable
VIIIe5	55	55	55
VIIIe6	55	55	55

Lowland Subsuite

LUC unit **IIIs3 (14,390 ha)—**Figures 70, 75

A feature of a number of rivers in Northern Hawke's Bay is that they are deeply incised along much of their course, in some cases as far as the coast. Two examples are the Mohaka and Waikari Rivers. A system of high terraces bordering these rivers was formed during the late Pleistocene (approx. 15000 yr B.P.) before the commencement of uplift (which is continuing today). The basement mudstones and sandstones have been overlain by deposits of greywacke gravel and sand derived from widespread erosion of the main ranges. Subsequently a series of tephras and loess has mantled these terraces. These can be divided into three major groups; Taupo Pumice (approx. 45 cm thick), overlying Waimihia Formation (approx. 45 cm thick), overlying a series of older, more weathered, compact tephras and loess (approx. 75 cm thick), including Rotoma Ash and Waiohau Ash.

These terraces, and a number of others in valley systems inland between Wairoa and Gisborne where these tephras overlie alluvium, have been mapped as IIIs3. The terraces are flat to undulating and the soils are either Mohaka sandy loam, Tuai sand or Tiniroto loamy sand.

Climate, slope and soil depth make these areas suitable for cropping. However, weakly developed soil structure, low natural fertility, slightly restricted drainage due to the compact layer of weathered tephra and a potential for slight wind erosion when cultivated, all limit the versatility.

Present uses are intensive grazing and maize cropping. There is a moderate potential for further cereal crops and root and green fodder crops, although care should be taken to prevent wind erosion. Potential stock carrying capacity is 15 su/ha and site index for *P. radiata* is 33-35 m.

LUC **unit** IIIe3 (4,750 **ha)—**Figure 71

This LUC unit is mapped on undulating to rolling downland where there is a moderate depth of Taupo Pumice and Waimihia Formation overlying more weathered tephras. Rainfall is between 1200 and 1600 mm p.a. and is generally adequate for pasture growth during summer. It occurs in association with a band of low hill country running from Waiwhare through Patoka to Tutira and Putorino.

Soils are typically Gisborne fine sandy loam, Waiwhare light sandy loam and Taupo light sandy loam. Because these soils are all sandy and coarse-textured, cultivation on this LUC unit can lead to slight to moderate wind, sheet and rill erosion. However under pasture, erosion is negligible.

Presently the unit is almost entirely in pasture, however it would be suitable for cereal and root and green fodder crops. Because of the erosion potential it would be advisable to establish windbreaks and practise contour cultivation. Potential stock carrying capacity is 20 su/ha and site index for *P. radiatais* 32-34 m.

LUC **unit** IVe2 (30,950 **ha)—**Figure 72

IVe2 occurs extensively throughout the Northern Hawke's Bay Region, often in association with IIIe3, VIel and VIe6. It is mapped where slopes are rolling to strongly rolling, usually in a downland situation, but also occasionally on plateaux, basins and broad ridge tops. An area of 2230 ha of marine terraces on Mahia Peninsula with composite yellow-brown pumice soils on yellow-brown loams, has also been mapped as IVe2 but is included in a separate suite of units confined to Mahia Peninsula (LUC suite 12).

IVe2 occurs principally below 600 m a.s.l. although it may occur up to 750 m a.s.l. Rainfall is mainly between 1200 and 2000 mm p.a. Soils are the same as those for IIIe3. In addition Tiniroto and Tuai soils occur in the Wairoa area.

With the increase in slope angle from IIIe3 the erosion potential has increased to severe wind, sheet and rill erosion when cultivated. As with IIIe3, erosion under pasture is negligible. Land use is intensive grazing, with a potential stock carrying capacity of 20 su/ha, and some exotic forestry. Site index for *P. radiata* is 28-33 m and in areas above 600 m this reduces to 23-28 m. Cropping would be limited to root and green fodder crops.

LUC **unit VIel** (97,240 **ha)—**Figures 38, 73, 74, 75

As slopes become too steep to cultivate safely the LUC unit changes from IVe2 to VIel. In VIel slopes are strongly rolling to moderately steep, and although the same tephras are present as in IVe2 their thickness decreases.

On these slopes soil slip and tunnel gully erosion occur. Soil slips are infrequent with only a slight potential. They usually remove the tephra mantle to expose weathered regolith. The underlying bedrock may be a variety of Tertiary or Quaternary rock types, principally mudstones and sandstones. Tunnel gullies occur sporadically, again with only a slight potential, and usually in areas where there is a thick layer of loosely compacted tephra such as Waimihia Lapilli overlying a more compacted, less porous layer.

The erosion potential on VIel is only slight and for this reason, together with the relatively low natural fertility of the yellow-brown pumice soils, this LUC unit may be better classified as Vis, where's' refers to soil limitations within the rooting zone. A recent study by Harmsworth *et al.* (1987) has quantified the effects of two storms in 1985 on a number of LUC units in the Otoi district. These LUC units are VIel, VIe6, VIelO, VIell, VIIe2 and VIIe9. Results of this study support the view that erosion is not a significant limitation for VIel.

VIel occurs extensively throughout the Region from sea level to approximately 600 m a.s.l. where rainfall is between 1200 and 1800 mm p.a. Most of the area is intensively grazed although there are significant areas of manuka and mixed indigenous scrub. Potential stock carrying capacity is 20 su/ha. Much of Esk, Mohaka, Patunamu and Wharerata State Forests are sited on VIel and VIe6 where there is a site index for *P. radiata* of 30-33 m.

A few areas of VIel west of Wharekopae occur at altitudes in excess of 600 m, and with an annual rainfall above 1800 mm p.a. These areas would be more correctly mapped as VIell.

LUC **unit VIe6 (111,150 ha)—**Figures 38, 74, 75

The largest LUC unit in this suite, VIe6, is found in association with VIel and comprises moderately steep to steep hill country. The tephra mantle is not as thick as in VIel, the underlying mudstones and sandstones being less than 1 m from the surface. The increase in slope angle has led to an increase in erosion potential. There is now a potential for moderate soil slip and slight tunnel gully, gully and sheet erosion. Soil slips are shallower than those in VIel but because of the shallower tephra mantle are more likely to expose the underlying mudstones or sandstones. In the Otoi study the eroded area and debris volume for VIe6 was more than twice that for VIel. Erosion is now a significant limitation and conservation planting may be necessary.

Soil types are the same as those in VIel, namely Gisborne, Tiniroto and Tuai hill soils. Present and potential uses are the same as those for VIel. While site index for *P. radiata* is the same at 30-33 m, potential stock carrying capacity is lower at 17 su/ha.

Upland Subsuite

LUC **unit IVcl (1,740 ha)—**Figure 76

This LUC unit is restricted to an area north of Lake Waikaremoana in the Urewera National Park. Slopes are undulating to rolling with a deep mantle of tephra consisting of thin Kaharoa Ash on Taupo Pumice on Waimihia Formation on older more weathered tephra.

The major limitation to use is climate. Altitude varies between 600 and 900 m a.s.l. with frosts and occasional snowfalls, and the rainfall is in excess of 2000 mm p.a. These conditions make IVcl marginal for cropping, being only suitable for occasional root and green fodder crops. If cultivated there is a potential for slight to moderate sheet, wind and gully erosion.

Soils are Matawai sand and Mamaku sand, both podzolised yellow-brown pumice soils. They are coarse-textured soils of low fertility, the high rainfall and altitude leading to strong leaching and the formation of an iron pan. Consequently potential production levels are low with a potential stock carrying capacity of 10 su/ha and a site index for *P. radiata* of 23-28 m.

The vegetation is almost entirely beech forest (red and silver beech) or beech-podocarp-hardwood forest (occasional rimu and miro), although there is some scrub and grassland in the Aniwaniwa Valley. This is a remnant from the period between 1910 and 1930 when part of the valley was farmed and some logging was carried out (Urewera National Park Board 1968).

LUC **unit VIell (55,810 ha)—**Figures 22, 76, 77

VIell is mapped on slopes similar to those of VIel and VIe6, but at altitudes between 600 and 1000 m where rainfall is 1800-2500 mm p.a. As rainfall and altitude increase to the west of the Region, particularly in the Urewera district, temperatures are lower, the tephra mantle is deeper and soils are strongly leached leading to the formation of an iron pan.

Soil types include Ruakituri sand and hill soils, Matawai sand and hill soils and Mamaku sand. These soils are podzolised and of lower natural fertility than those of VIel and VIe6. Although still suitable for grazing and forestry, production potential has dropped to a carrying capacity of 11 su/ha and a site index for *P. radiata* of 22-29 m.

There is a potential for moderate soil slip and slight gully and tunnel gully erosion due to the high rainfall and deep tephra mantle which overlies less permeable sandstones and mudstones. Some areas with strongly rolling to rolling slopes have been mapped as VIell but because of a lower erosion potential would be better mapped as Vic.

VIel 1 occurs mainly in and around the margins of the Urewera National Park and on a few isolated high points such as Whakapunake. Therefore much of the unit is in indigenous forest, mainly beech or beech-podocarp hardwood. Small areas of pasture and scrub occur particularly in the Ruakituri Valley.

LUC **unit VIc3 (3,320** ha)—Figures 75, 78

The Maungaharuru and Te Waka Ranges are prominent features of the Northern Hawke's Bay landscape. They are north-east/south-west trending ridges with steep scarp slopes facing north-west towards the Mohaka River and long broken dip slopes facing towards Hawke Bay. Both ranges are in excess of 1000 m a.s.l. for much of their length, the Maungaharuru Range reaching a height of 1307 m a.s.l.

VIc3 is mapped along these ranges between 800 and 1100 m a.s.l. where a cap of limestone, and in some places sandstone, form strongly rolling to moderately steep basins and plateaux. The area is mantled by tephra consisting of Taupo Pumice on Waimihia Formation on more weathered tephra. Soil types include Titiokura sandy silt, Taupo sandy silt and Ngaroma sandy silt, hill soil.

At this altitude and in such an exposed location the major limitation to use is the climate. Being formed on limestone the slopes are stable, with only a potential for slight sheet and wind erosion of the tephra mantle under pasture. However it is important to maintain a complete pasture cover as exposure of the underlying tephras would lead to severe erosion. The rainfall is in excess of 2000 mm p.a. with a high incidence of cloud. Frosts and snowfalls are numerous in winter and strong winds are common, particularly from the north-west and south-west. These conditions combine to depress plant growth.

Present vegetation consists of pasture, red tussock, manuka, and remnant forest (red beech). The potential stock carrying capacity is 12 su/ha, but because of the altitude VIc3 is unsuitable for production forestry.

LUC **unit VIIel4 (49,260** ha)—Figures 76, 80

This LUC unit occurs in association with VIell wherever there is a severe to very severe potential for erosion. Vile 14 is mapped either on steep to very steep slopes in the same altitudinal range as VIell (600-1000 m) or on moderately steep to strongly rolling slopes between 1000 and 1200 m. Below 1000 m the numerous ridges in the Ureweras are mapped as Vllel4 and the basins as VIell.

Present erosion is nil to slight debris avalanche, as most of the unit is in indigenous forest, but if converted to pasture there is a potential for severe soil slip erosion at lower altitudes, increasing to very severe soil slip at higher altitudes. Minor erosion types include gully and wind. This increase in erosion potential is a result of steep slopes, the presence of a loose ash mantle and a rainfall in excess of 2000 mm p.a.

The mantle of tephra is of variable thickness, being thickest on the easier slopes and shallow to absent on steep slopes. The tephra overlies banded sandstone, which consists of alternating thick beds of sandstone and thin beds of mudstone, commonly dipping to the south-east. Soils are podzolised yellow-brown pumice soils and related steepland soils, either Waikaremoana steepland soils or Matawai hill soils.

Vegetation is mainly beech forest (red or silver), or beech-podocarp-hardwood forest (rimu, miro) and as with VIell most of the unit occurs in and around the margins of the Urewera National Park. Therefore very little of this LUC unit has or is likely to be developed. Like the areas of class VIII, an important function of Vile 14 is soil conservation and water management. On areas where grazing is carried out, maintenance of a complete pasture cover is necessary and burning for land development should be strictly controlled. Logging operations should be designed in such a way as to minimise the erosion hazard.

Stock potentials are low at 4 su/ha and site index for *P. radiata* is low to medium at 20-29 m.

LUC **units VIIIe2 (1,650** ha)—Figure 79, **VIIIe5 (6,760** ha)—Figure 22, **VIIIe6 (2,280** ha)—Figure 80 and **VIIIe7 (1,550** ha)

A feature of the central and southern Ureweras is the distinctive north-east/south-west trending ridge and valley systems. These are formed of strongly bedded Tertiary sandstones and mudstones. These ridges or cuestas consist of north-west facing scarps and south-east facing steep dip slopes. The four class VIII LUC units mapped in this suite all occur on this landform. They are distinguished from one another on the basis of slope and erosion potential. The rainfall for these LUC units is in excess of 2,500 mm p.a. and the vegetation is beech forest (red, silver, mountain).

Bluffs and very steep scarps and gorges are mapped as VIIIe2. This LUC unit also occurs elsewhere throughout the Region where it is included with LUC suite 7, 9 or 10. The total area of VIIIe2 in the Northern Hawke's Bay Region is 11,730 ha. In this suite VIIIe2 occurs as near vertical bluffs of banded sandstone, such as the prominent Panekiri Bluff at Lake Waikaremoana or as gorges of the Waiau River. Slopes are long and very steep with extensive outcrops of sandstone. Soils are very shallow to absent with very little to no tephra. Soils are either Waikaremoana series (steepland soils related to podzolised yellow-brown pumice soils) or Mahoenui series (steepland soils related to yellow-brown earths). Present erosion is moderate debris avalanche with a severe to very severe potential if developed.

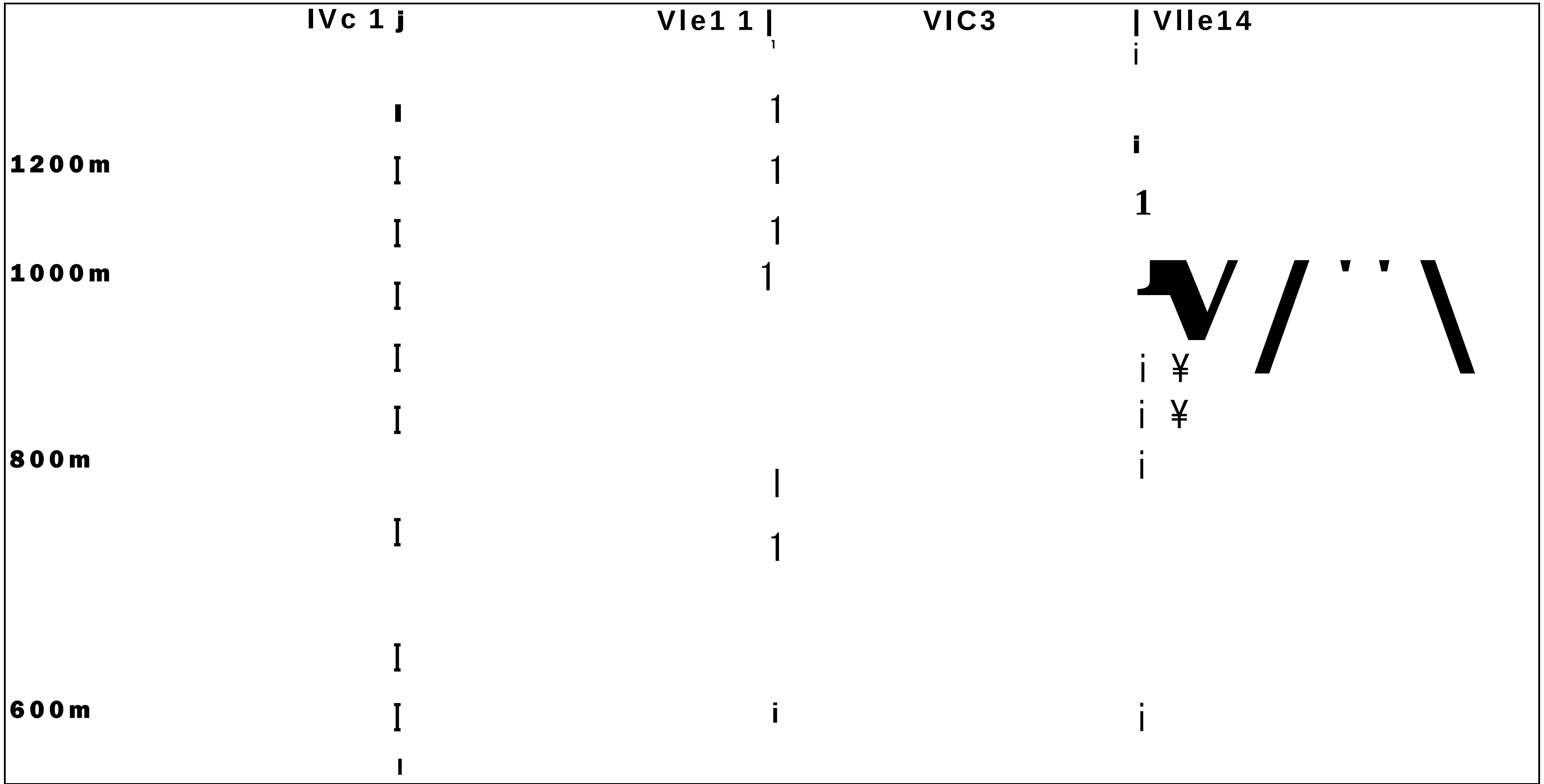
VIIIe5 and VIIIe6 are both mapped on long very steep mountain slopes. Tephra is thin to absent and overlies banded sandstone. The difference between the two LUC units is in erosion severity. Erosion on VIIIe5 is slight to moderate debris avalanche, while on VIIIe6 it is severe to very severe. The reason for the more severe erosion on VIIIe6 is not clear. Factors that may be involved include: steeper slopes, higher altitude, faults or crush zones, or localised storms. In the case of VIIIe5 erosion potential is very severe to extreme, while in VIIIe6 it is extreme if the forest cover is removed. Soils for both LUC units are Waikaremoana steepland soils which are shallow, strongly podzolised and of low natural fertility. An example of VIIIe5 is the Ngamoko Range at Lake Waikaremoana, while VIIIe6 is mapped on the slopes on Mt Manuoha. VIIIe5 has also been mapped in the Northern Ruahine Range near Ruahine Corner. Both these LUC units are also mapped on greywacke, where they are included in LUC suite 15.

On strongly rolling to moderately steep dip slopes there is a sequence of 3 LUC units with increasing altitude. Areas below 1000 m a.s.l. are mapped as VIell, areas between 1000 and 1200 m a.s.l. are mapped as VIIel4 and VIIIe7 is mapped above 1200 m a.s.l. VIIIe7 therefore is exposed to strong winds and very heavy rainfalls. Because slopes are not steep there is a relatively deep mantle of tephra. On such slopes sheet and wind erosion rather than debris avalanche are the main erosion types. Although erosion is the major limitation, climate is also a significant limitation. Present erosion is limited to slight to moderate sheet and wind, although there is a potential for very severe erosion if the sub-alpine scrub and mountain beech is removed. Gully and soil slip may also occur.

The erosion, climate and low soil fertility make all four of these class VIII LUC units unsuitable for productive use. The forests on these LUC units have a protective function and their condition should be maintained or improved for soil conservation and water management. These goals will be met through the prevention of logging and burning, and the control of noxious animals.

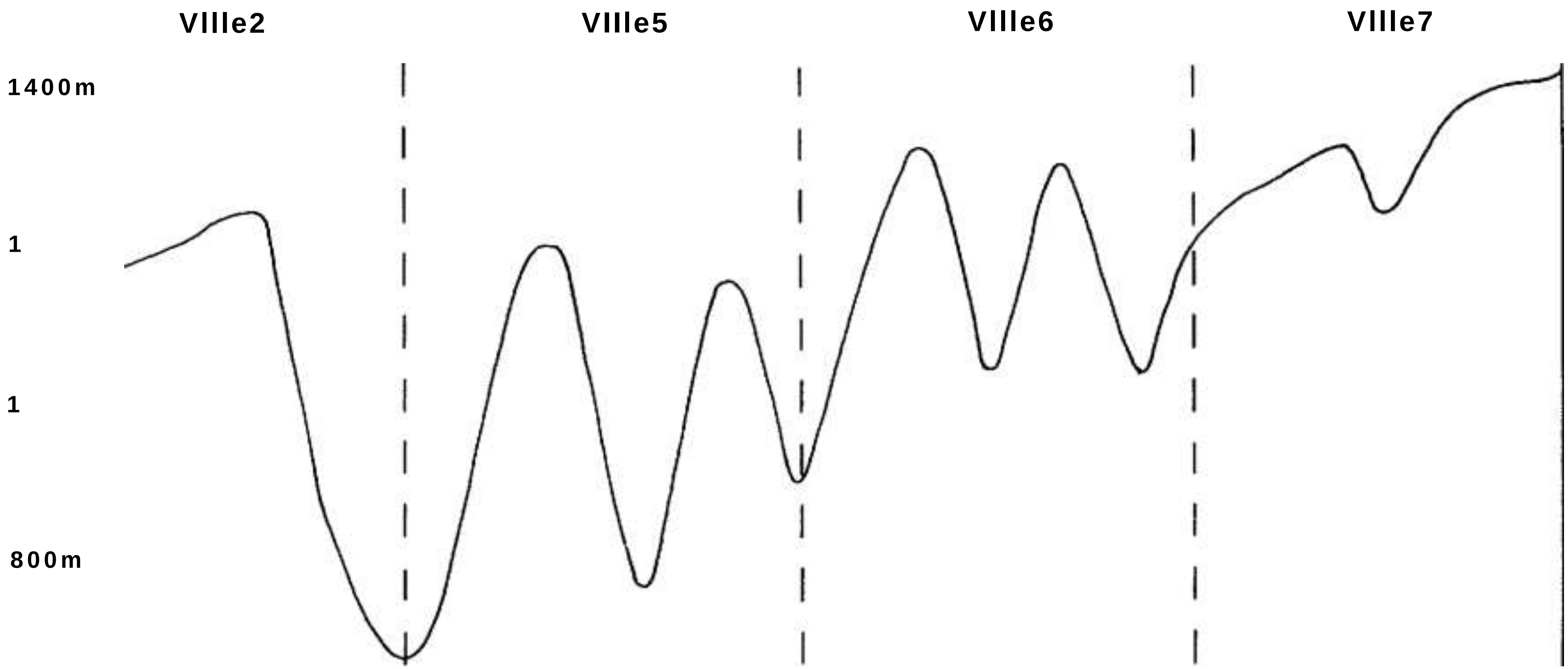
III s3 |	HIe3 |	IVe2	VIeI	VIe6
800m 600m 400m	| 1 1 /T			
■ 200m sea level	i i			
Slope	A, A + B B, C	C + D	D+E, E+D	E, E + F
Altitude	<400m | <400m	<750m	<600m	<600m
Rainfall	1 200-1600mm pa| 1 200-1 600mm pa |	1 200-2000mm pa	1 200-1 800mm pa	I1200 -2000mm pa
Erosion Potential	1W (when cultivated)! 1-2Sh, 1-2W, 1-2R (when cultivated) |	3Sh, 3W, 3R (when cultivated)	IT, 1sSI	|2sSI, 1T, 1Sh, 1G

Figure 69a: Relationship between LUC units on landforms with a mantle of Taupo airfall tephra (lowland subsuite).



Slope	B, B + C	D, E	D+E, E+D	D, E, F
Altitude	600-900m	600-1000m	800-1100m	600-1200m
Rainfall	>2400mm pa	1800-2500mm pa	2000mm pa	2000-3000mm pa
Erosion	1-2SH, 1-2W		1 Sh, 1 W	[illegible]

Figure 69b: Relationship between LUC units on landforms with a mantle of Taupo airfall tephra (upland subsuite.)



Slope	G	G	G	D + E, E + D
Altitude	600-1300m	600-1200m	900-1300m	1 200-1400m
Rainfall	2500- , 3500mm pa	2500-350Omm pa	3000-3500mm pa	+ 3000-3500mm pa
Erosion Potential	3-4sSi, 2Sh, 1G	4-5sSI, 2G, 2W	5sSI, 2G, 2W	4Sh, 4W, 2G, 2sSI

Figure 69c: Relationship between LUC units on landforms with a mantle of Taupo airfall tephra (upland subsuite.)

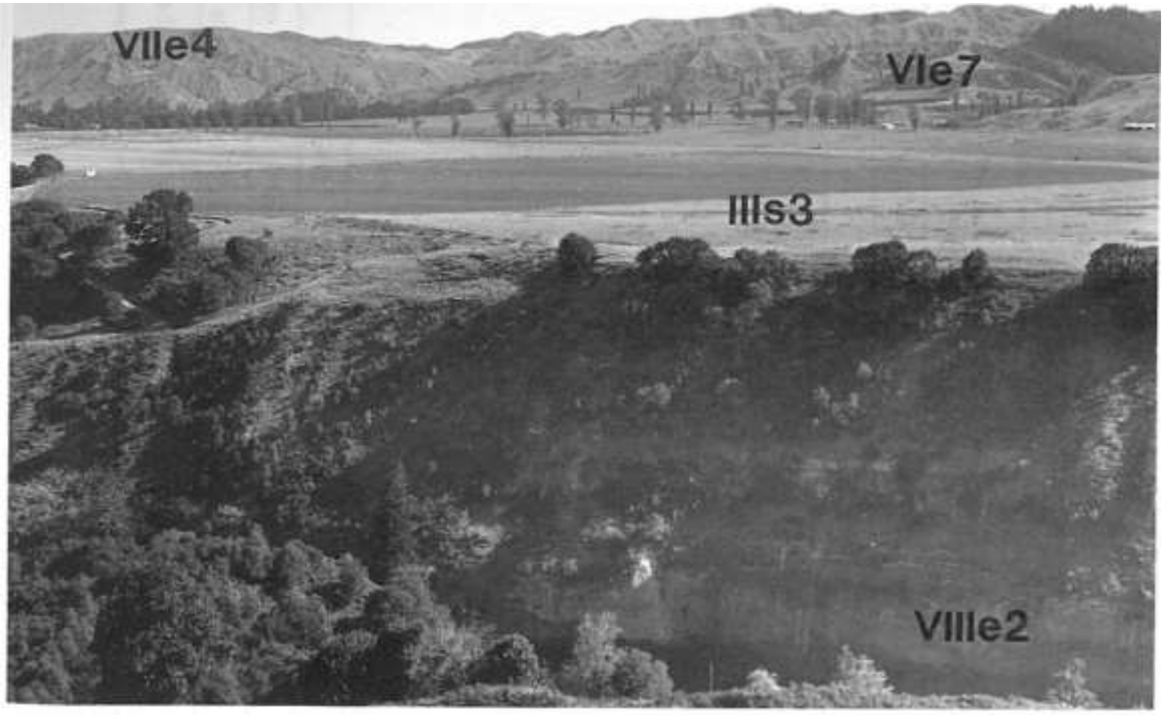


Figure 70: IIIs3. Mohaka River, north-west of Raupunga. N115/527925, looking south. VIIIe2 in foreground (LUC suite 9), and VIe7 and VIIe4 in background (LUC suite 8).

Figure 71: IIIe3. Napier-Taupo Road, south of Te Pohue. N124/143618, looking south-west.

Figure 72: IVe2. Tiniroto. N106/955249, looking north-east.

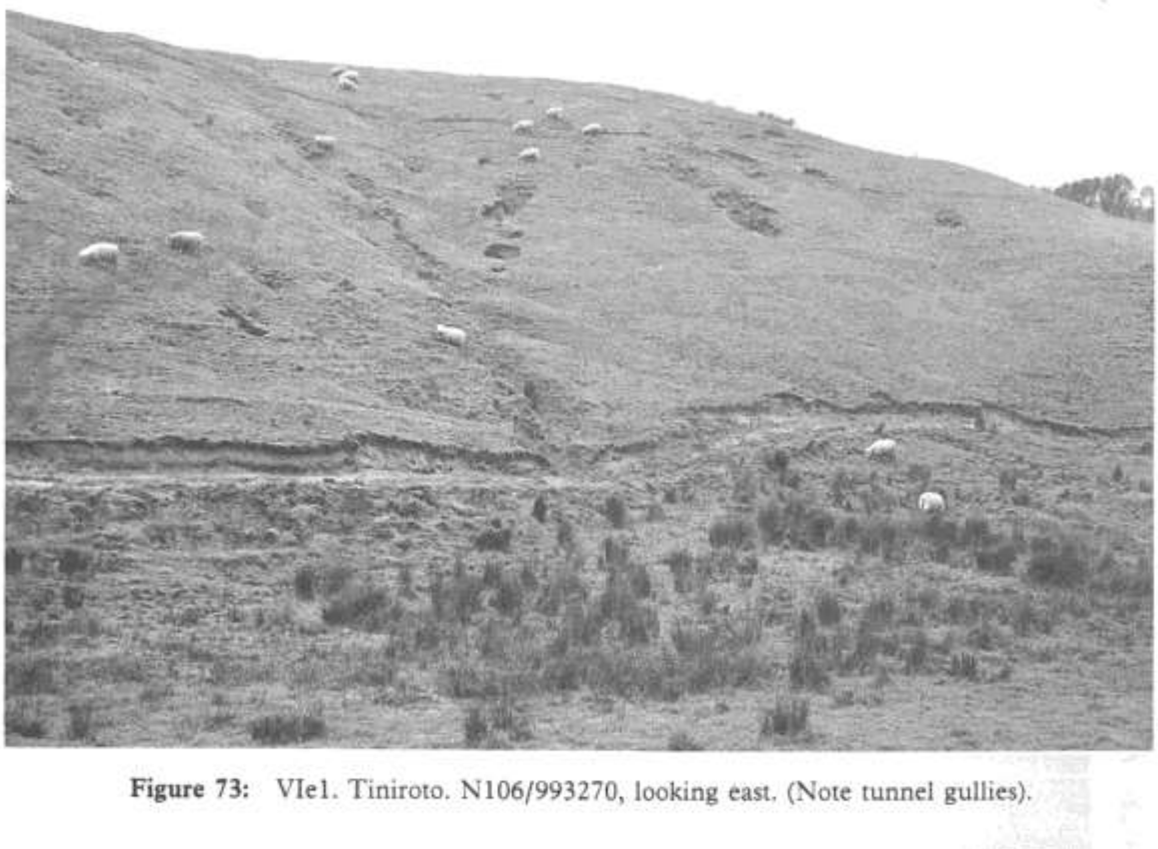


Figure 73: VIe1. Tiniroto. N106/993270, looking east. (Note tunnel gullies).

Figure 74: VIe6 in background. Waiau River, east of Putere. N105/560055, looking south. VIel in foreground. Vile 11 in centre (LUC suite 7).

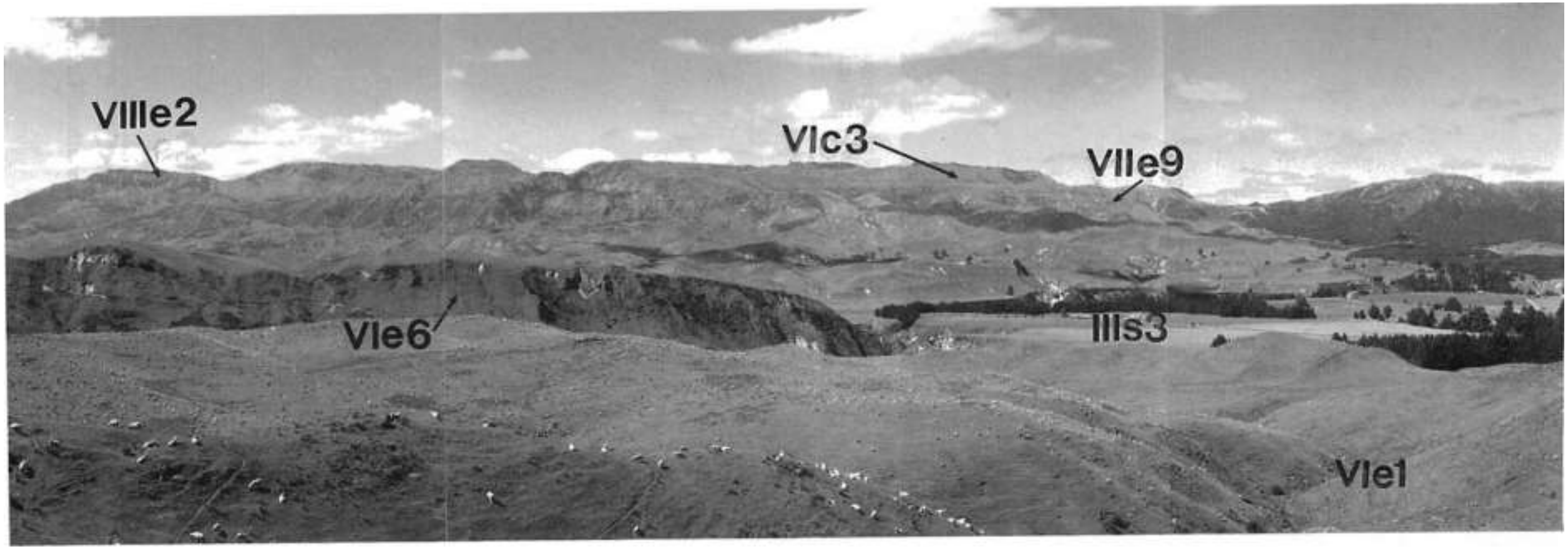


Figure 75: View across Mohaka River from Napier-Taupo Road. Nl 14/065775, looking south-east. VIel in foreground VIe6 left centre, IIIs3 right centre, VIc3 centre background. VIIe9 and VIIIe2 in background (LUC suite 9).

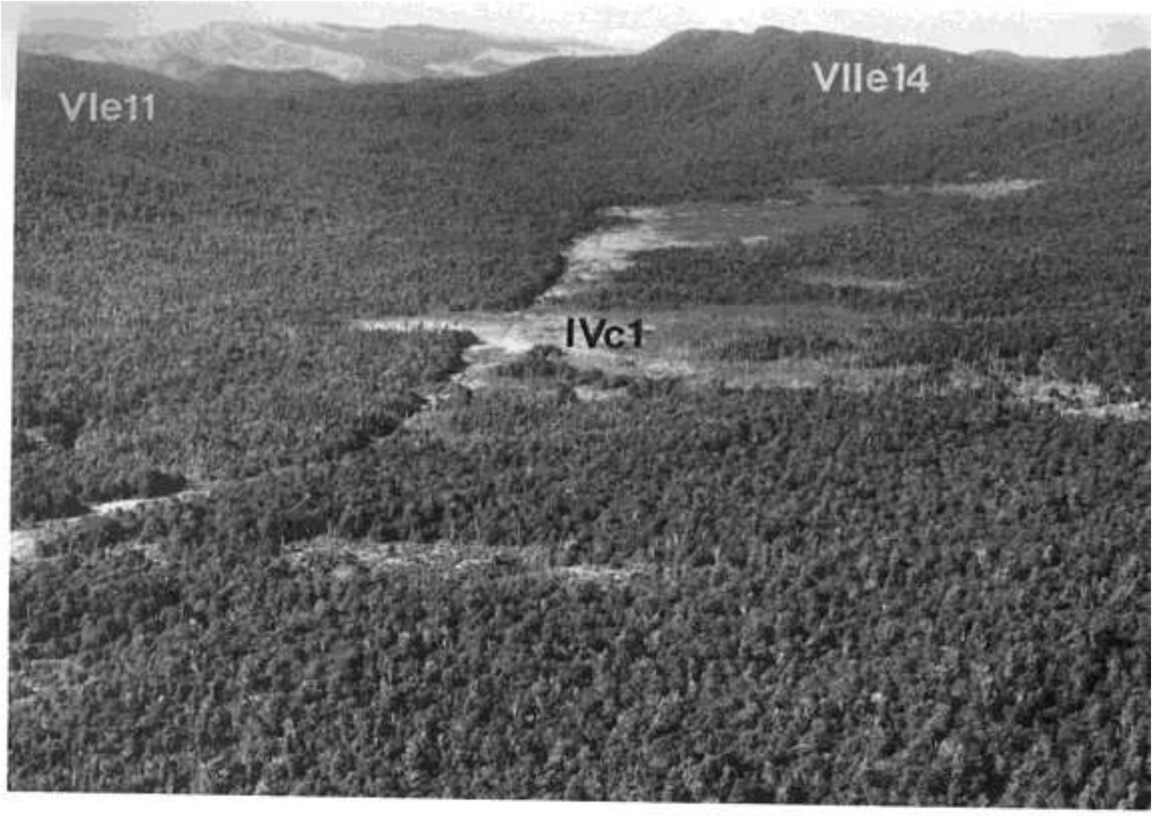


Figure 76: IVc1. Aniwaniwa Valley, Lake Waikaremoana. N96/625308, looking north-east. VIe11 in left background and VIIe14 in right background. Photo: N A Trustrum

Figure 77: VIe11. Whakapunake, south of Tiniroto. N106/975176, looking west.

Figure 78: VIc3. Maungaharuru Range. N114/150793, looking north. Photo: P R Stephens

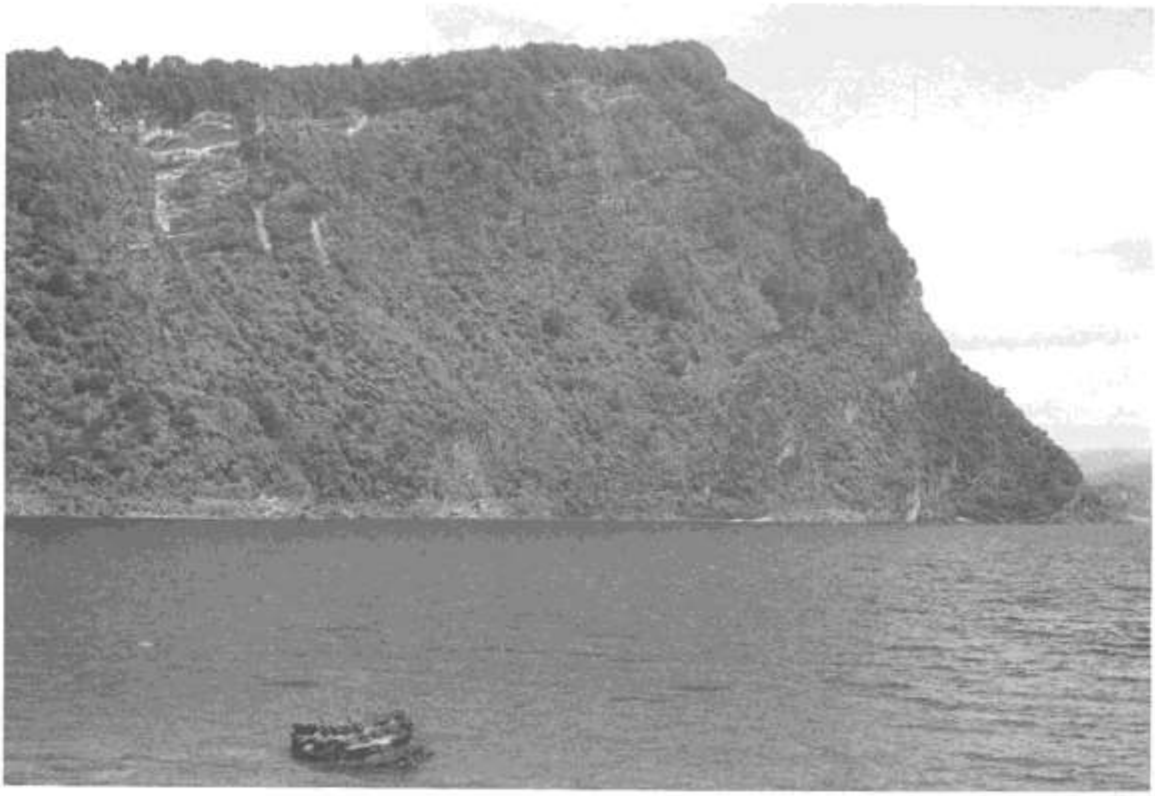


Figure 79: VIIIe2. Panekiri Bluff, Lake Waikaremoana. N105/530233, looking west.

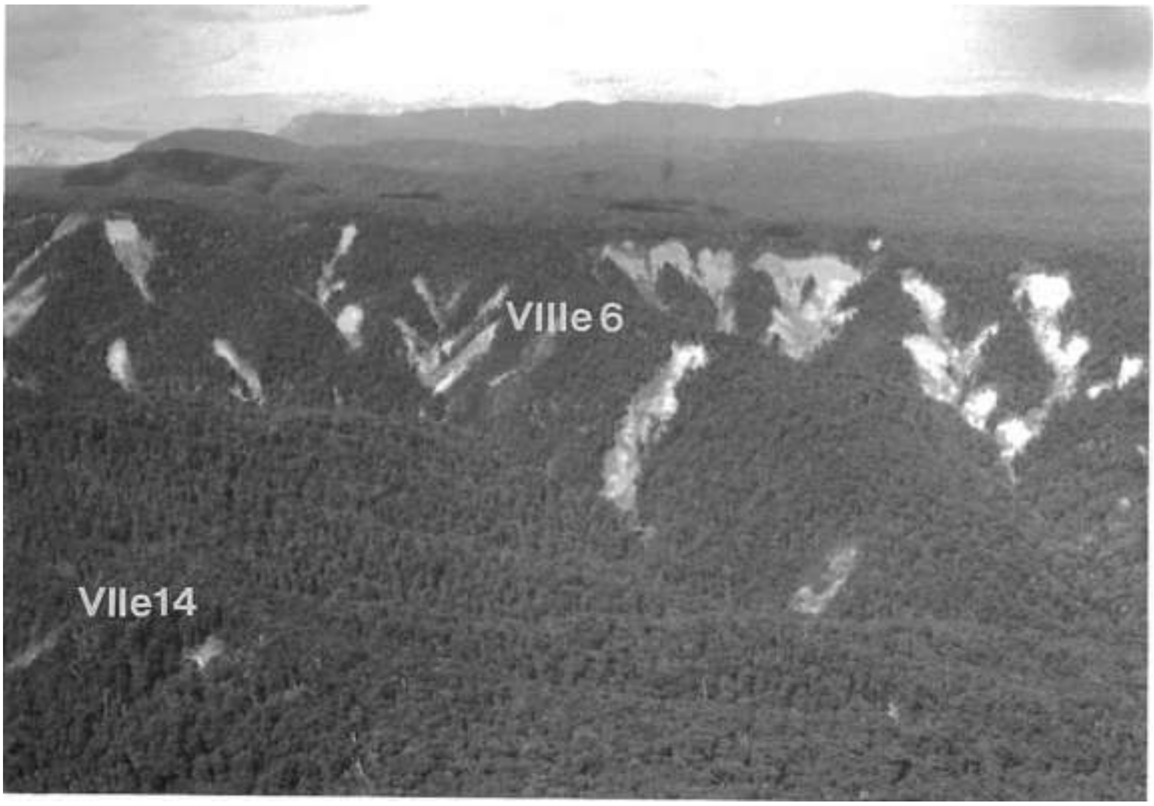


Figure 80: VIIIe6. Mt Manuoha, north of Lake Waikaremoana. N96/530390, looking south-east. VIIel4 in foreground. Photo: N A Trustrum

LUC SUITE 12: RAISED MARINE TERRACES WITH A SHALLOW MANTLE OF WAIMIHIA LAPILLI OVERLYING MORE WEATHERED TEPHRA

This suite is mapped on Mahia Peninsula and Portland Island on flat to rolling raised marine terraces. The terraces occur in the south-west of the peninsula as a narrow coastal band dissected by a series of streams, and more extensively in the north-east near Table Cape where they extend up to 4 kms inland (Figure 81).

There are 3 LUC units in the suite; IIIe2, IVe2 and VIcl with a total area of 3,410 ha or 0.3% of the Region. The features that characterise this suite are: composite yellow-brown pumice soils on yellow-brown loams, flat to rolling slopes, and a location exposed to salt-laden winds. LUC units within the suite are defined on the basis of slope and degree of exposure to wind.

Erosion and climate are regarded as the major limitations to use and in both cases wind is the main factor. The cropping potential of these LUC units is limited by wind erosion and the effect of strong salt-laden winds on plant growth. However land use is presently restricted to pastoral farming, mainly because of the distance from main centres.

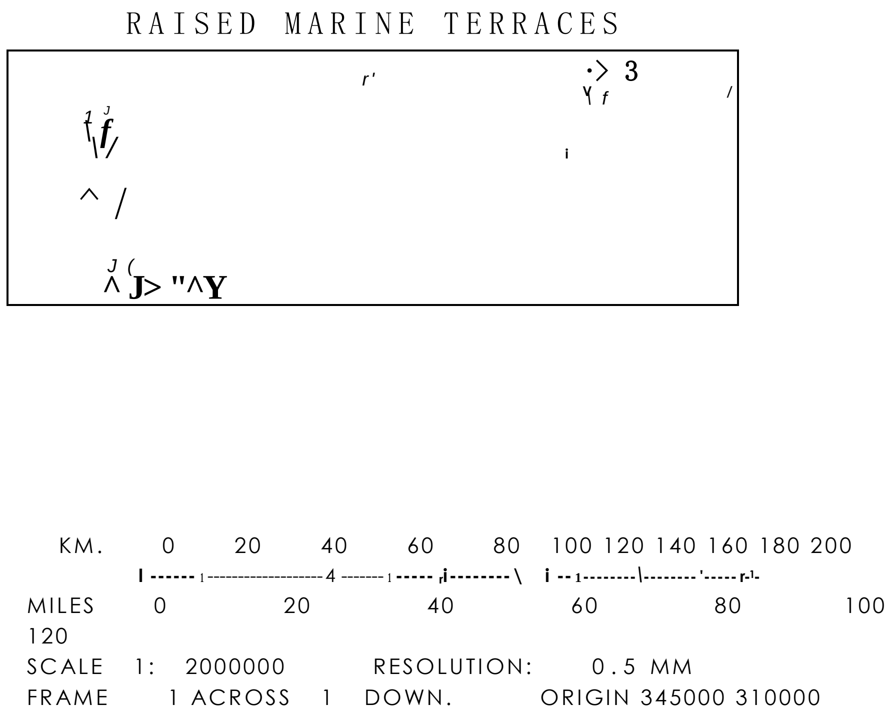


Figure 81: Location of LUC suite on raised marine terraces with a shallow mantle of Waimihia Lapilli overlying more weathered tephra.

Climate

The climate presents few limitations to plant growth other than that of wind. Summers are very warm, while winters are mild with few frosts. Annual rainfall is 1200-1400 mm, although because of annual and monthly variability droughts can occur.

Mahia Peninsula is a former island linked to the mainland by a narrow bar of sand or tombolo. As such it is exposed to the sea on nearly all sides. The LUC units in this suite are situated along the coast and are therefore exposed to strong salt-laden winds.

Rock Type

The terraces have been mantled by a number of tephras from both the Taupo and Rotorua areas. Taupo Pumice, the major tephra over much of Northern Hawke's Bay, decreases in thickness towards the east until at Mahia Peninsula it is practically absent. Here the upper-most tephra is Waimihia Lapilli (which underlies Taupo Pumice to the west). This is a shallow layer (30-50 cm) of loose, uniform lapilli, strong brown to yellow in colour. It has an age of approximately 3,400 yr B.P. and a source just east of Lake Taupo (Healy *et al.* 1964).

Beneath Waimihia Lapilli are older rhyolitic tephras originating from the Rotorua area, such as Rotoma Ash (7,300 yr B.P.) and Waiohau Ash (11,200 yr B.P.) and loess. These tephras and the loess are more weathered and compacted. They appear as a fine-grained, strong brown to yellowish brown layer up to several metres thick.

Beneath these tephras are Tertiary rocks, mainly mudstone interbedded with sandstone. However these underlying rocks have no effect on land use.

Soils

Soils are those of the Mahia and Kopuawhara series from the Wairoa County Survey (Rijkse unpublished), and are classified as composite yellow-brown pumice soils on yellow-brown loams. They have developed on the tephra and loess deposits. The upper parts of the soil profiles have the characteristics of yellow-brown pumice soils (from Waimihia Lapilli) and the lower parts of the soil profiles have the characteristics of yellow-brown loams (from older weathered tephra and loess).

Soils of the Kopuawhara series occur in the south-west and on Portland Island, and those of the Mahia series in the north-east. Mahia soils are well drained while Kopuawhara soils are only moderately well drained and have a shallower layer of Waimihia Lapilli. Soils are typically sandy loams and fine sandy loams.

Because the layer of Waimihia Lapilli is only shallow, plant roots are generally able to penetrate the underlying tephra and loess beds which have a higher moisture-holding capacity and a better supply of plant nutrients.

Mahia soils also occur near Nuhaka, where they overlie mudstones subject to deep-seated erosion. Here they are mapped within LUC suite 5.

Topography

The terraces are between 50 and 150 m a.s.l. and dip towards the coast where they terminate in cliffs. Slopes range from flat (40%) to undulating (13%) to rolling (47%). Slopes recorded in the undulating and rolling groups partially reflect the angle of dip of the terraces towards the coast and partially the undulating or rolling nature of the surface. The terrace surfaces are dissected by numerous small incised stream channels. These have no effect on the present pastoral use of the terraces, but they would present a hindrance to cropping.

Erosion

Erosion is negligible under the present vegetation cover of pasture. However, if cultivated the friable sandy soils have a potential for wind erosion. This potential may vary from slight to severe depending upon location. In general the erosion potential is greater for the more exposed areas at the south of the peninsula, and for those areas nearest to the coastline. In addition, on rolling slopes under cultivation there is also a potential for sheet and rill erosion.

Vegetation

The vegetation is mainly pasture except in the incised stream channels where manuka and mixed indigenous scrub have generally been allowed to establish. On more exposed terraces on the south-west side of the peninsula the pasture contains scattered manuka and tauhinu. In several places near Table Cape gorse has spread onto terraces from nearby scarps.

Several small stands of indigenous forest occur in the north-east, remnants of the forest that once covered much of this area. Cropping is limited to occasional root and green fodder crops and cereals.

Land Use and Land Management

Sheep and cattle farming is the main land use with minor dairying near Mahia township. Scrub control is a continuing minor problem in some areas.

At present cropping is limited to root and green fodder crops and cereals, and is carried out only as part of normal farming practice. There is however a considerable potenital for horticulture in some areas. Physically the terraces have soils with medium to high natural fertility and adequate drainage, while tne climate is mild. There is however a need for shelter. At present there are few windbreaks and these would need to be considerably increased if horticulture or other forms of cropping became a major land use. To date, however, the distance of Mahia Peninsula from main centres has been a major limitation to such changes in land use.

Land Use Capability Units

This suite contains 3 LUC units, IIIe2, IVe2 and VIel. The potential for cropping on these LUC units is limited by the effects of wind. In more sheltered locations LUC units such as these would be capable of growing a wider range of crops and would then be mapped as class II where slopes are flat to undulating or class III where slopes are rolling.

LUC unit IIIe2 (1100 ha)—Figure 82

The more sheltered terraces on Mahia Peninsula occur in the north-east near Mahia township and Table Cape. Here, where slopes are flat to undulating, there is a potential for horticulture where adequate shelter has been provided. Because there are moderate climatic limitations to the range of crops that can be grown and because there is a slight to moderate potential for wind erosion these areas are mapped as IIIe2.

Soils are those of the Mahia series. They are deep, friable, well drained soils, yet with good moisture retention in the compact lower horizons. Intensive grazing is the main land use and there is a potential for a stock carrying capacity of 20 su/ha. There is a small amount of dairying, and some root and green fodder crops and cereals are grown. Site index for *P. radiata* is high at 33-35 m.

LUC unit IVe2 (2230 ha)—Figure 83

Areas in the north-east where slopes are rolling are mapped as IVe2. Here parent material and soils are the same as for IIIe2 but the increase in slope leads to an increase in erosion potential under cultivation. Under a grass cover there is little or no erosion, but when cultivated there is not only a potential for moderate wind erosion but also for severe sheet and rill erosion. In addition to windbreaks, contour cultivation is necessary. Present land use is the same at 20 su/ha, but site index for *P. radiata* is slightly lower at 28-33 m due to the slightly shallower soils and more exposed sites.

In the south-west of the peninsula the terraces are only undulating and at the southernmost point they are flat. However these ares are mapped as IVe2 rather than IIIe2 because of the exposed location and the potential for severe wind erosion. The soils are those of the Kopuawhara series which are similar to the Mahia soils but are only moderately well drained and with a slightly less well developed structure.

LUC unit IVe2 mapped on Mahia Peninsula is in fact part of a much larger area of IVe2 with yellow-brown pumice soils (LUC suite 11) which is mapped extensively throughout the Region. Although there is a potential for greater wind erosion, and although Taupo Pumice is practically absent, the area on Mahia Peninsula has been included in IVe2 because at the class IV level the land use capability is similar. At more detailed scales of mapping a separate LUC unit for the area on Mahia Peninsula would be warranted. However at the class III level areas on Mahia Peninsula have been separated from the class III unit on yellow-brown pumice soils which is mapped throughout the rest of the Region, because of the wider range of crops that can be grown.

LUC unit VIcl (80 ha)—Figure 84

Portland Island, situated about 2 km off the southern tip of Mahia Peninsula, is a continuation of the raised marine terrace system on the mainland. As on the mainland the soils are those of the Kopuawhara series, however here the terraces are mapped as VIcl, because although the rolling slopes are capable of being cultivated the very exposed location makes the potential for wind erosion too great for cropping. However under good pasture management the erosion risk is slight and the climate is the major limitation to production. Windbreaks would still be a valuable asset for stock protection. Present use is grazing, with 10 su/ha for potential stock carrying capacity, and the site index for *P. radiata* is 20-24 m.

Figure 82: IIIe2. South of Mahia township, Mahia Peninsula. Nl 17/300845, looking north-east.

Figure 83: IVe2. West coast of Mahia Peninsula. Nl 16/210755, looking south.

Figure 84: VIc1. Portland Island, south of Mahia Peninsula. N126/233604, looking north. VIIIe3 in foreground (LUC suite 7). Photo: N A Trustrum

LUC SUITE 13: LOW HILLS WITH A MANTLE OF TAUPO AIRFALL TEPHRA OVERLYING COARSE LAPILLI

This suite is characterised by deep beds of coarse erodible lapilli which occur beneath deposits of Taupo Pumice. Lapilli beds occur over a wide area, especially in the centre of the Region where they reach the coast. However this suite is only mapped where there is sufficient depth of loose, coarse-textured lapilli to have an effect on land use capability. There are 3 LUC units in the suite, IVe3, Vie 15 and Vile 19, and they occur near the southern boundary of the Upper Rangitaiki Plains. They are separated on the basis of slope and erosion potential and are mapped on the lower slopes of the hills bordering the terraces of the Taharua, Ripia, Waipunga and Hautapu Rivers (Figure 85).

Despite a harsh climate and poor soils it is the erosion potential which is the major constraint to land use. Once the lapilli beds are exposed serious gully erosion will develop.

The area of the suite is only 16,540 ha (1.4% of the Region), however it is continuous with a much larger area of lapilli in the Bay of Plenty-Volcanic Plateau Region with equivalent LUC units.

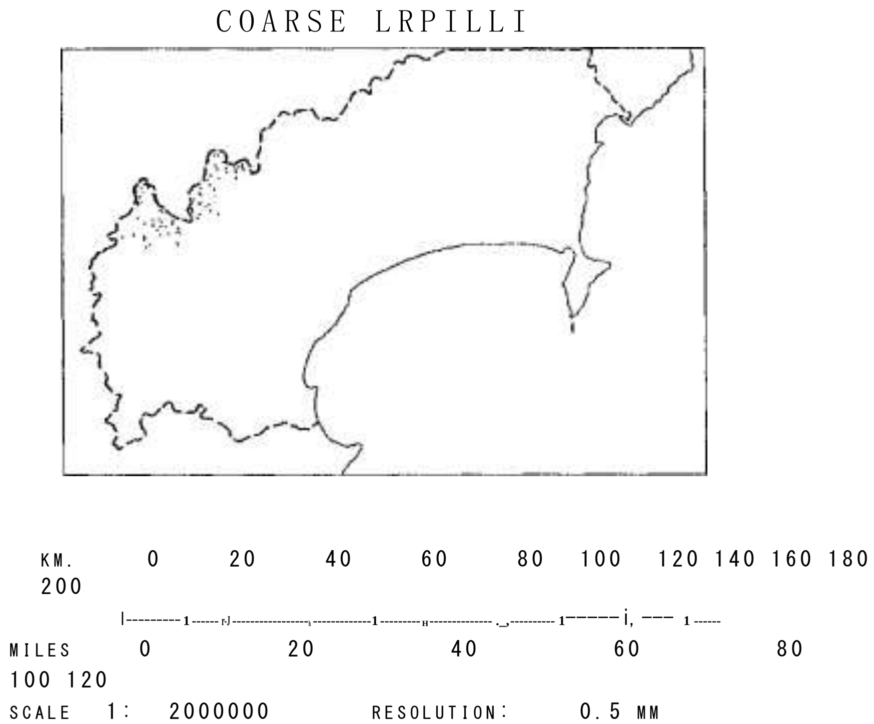


Figure 85: Location of LUC suite on low hills with a mantle of Taupo airfall tephra overlying coarse lapilli.

Climate

Located at between 700 and 1000 m a.s.l. on the margin of the Upper Rangitaiki Plains, the suite has a cool climate with a high rainfall. Low temperatures restrict plant growth with frosts occurring at any time of the year. At Waimihia Forest there is an average of 118 ground frosts per year. Occasional snowfalls also occur. Annual rainfall is between 2000 and 2500 mm p.a. and this is evenly distributed throughout the year.

Rock Type

Because the suite consists of low hills close to the Taupo Volcanic Centre slopes are mantled with deep tephra. This mantle consists of a number of different tephras, the depth and distribution of which have been mapped by Pullar (1980). The most important of these from the point of view of land use capability is Waimihia Lapilli, a rhyolitic deposit with an age of approximately 3,400 yr B.P. It is a member of the Taupo Sub-group and constitutes the main member of the Waimihia Formation (Healy *et al.* 1964, Walker 1981). It is a yellow-brown, very loose, coarse pumiceous material with a thickness of approximately 2 m in the east at the head of the Waipunga catchment and 3-5 m in the west at the head of the Taharua catchment.

Overlying Waimihia Lapilli is 1-2 metres depth of Taupo Pumice Formation which consists of a number of tephras deposited approximately 1850 yr B.P. (Healy *et al.* 1964). This material forms the uppermost layer, on which soil development has occurred.

Beneath Waimihia Lapilli are a number of other more weathered tephras, both rhyolitic (including Whakatane Ash, Rotoma Ash and Waiohau Ash) and andesitic (unnamed). Principally because of their age and degree of weathering they behave in a similar manner in terms of land use capability, and for this reason they have been grouped together in the NZLRI and mapped as 'Mo' or tephras older than Taupo Pumice Formation (Crippen and Eyles 1985). They are browner in colour, more weathered, finer textured and more compact than the more recent overlying tephra. Because of the convention of recording stratigraphically only the three most important rock types or cover deposits, 'Mo' tephras were not normally recorded in this suite.

Underlying all these tephra deposits are Te Whaiti ignimbrites or Kaweka and Urewera greywacke. The Te Whaiti ignimbrites are welded pyroclastic flow materials which have given rise to a subdued topography. They are the underlying rock for 22% of the suite and flank the greywacke which forms steeper hills and is the underlying rock for 78% of the suite.

Soils

Soils developed on these tephras are classified as yellow-brown pumice soils. They have friable topsoils with weakly developed structures and very friable to loose subsoils. They are also free draining. High annual rainfall, low temperatures and a mor-forming vegetation lead to downward movement and accumulation of iron and humus in the subsoil. Soils are therefore podzolised yellow-brown pumice soils. This leaching of material has added to the low nutrient status of these soils.

The soils are mapped by the Taupo County Survey (Rijkse in prep.) and are typically those of the Tihoi, Makahu and Pukerimu series. Also included is a small area of Oruanui soils at the head of the Taharua catchment. Oruanui soils are only moderately leached and are classified as yellow-brown pumice soils.

Topography

The suite is located along the main catchment divide separating the rivers flowing into Hawke's Bay from those flowing into the Bay of Plenty. The altitude ranges from 700-1000 m a.s.l. Relief is subdued, consisting of low rolling downland rising to moderately steep hills. This terrain has a characteristic rounded, smooth appearance with slopes having generally convex profiles. These downs and hills flank terraces of flow tephra that have infilled the river valleys in the area.

Erosion

The mantle of Taupo Pumice, and especially the underlying Waimihia Lapilli, are particularly erodible when exposed. Sheet and gully are the two main erosion types, while erosion potential varies from slight to severe, depending upon slope angle. Minor soil slip erosion may also occur. On rolling slopes there is also a potential for severe sheet, rill and gully erosion when cultivated.

Sheet erosion occurs where the soil has been exposed. This may be due to cultivation, overgrazing, land clearance, stock and farm tracks, fencing etc. Under these conditions particles are removed by sheet wash and ultimately water is concentrated by surface irregularities into small depressions and rills are formed.

Sheet and rill erosion occur in the surface layers but if these more compact layers are broken then gully erosion will develop in the exposed lapilli. The lapilli is highly susceptible to removal by water and this leads to undermining and collapse of the overlying layers at the margins of the gully. The gullies are typically small, elongate and relatively shallow, eroding only to the base of the Waimihia Lapilli. At present gully erosion is not common and is restricted to areas in pasture or scrub where significant soil disturbance has occurred.

Vegetation

Although the terrain consists of downland and easy hill country, at the time of the survey only 21% of the suite was in productive use. This is due to the isolated location on the margins of the main ranges, the cool climate and the low natural fertility. Broadly the vegetation can be grouped into 5 categories dominated by the following: pasture with small areas of scrub (mainly manuka) 13%, exotic forest 8%, tussock and *Dracophyllum2%,* indigenous forest 31% and scrub 46%. Areas of pasture and exotic forest are confined to the easier terrain while scrub and indigenous forest occur mainly on the steeper hills. Of the indigenous forest, this consists of lowland beech forest in the Taharua, Ripia and Hautapu catchments and lowland podocarp-hardwood forest, much of which has been logged, in the Waipunga catchment.

Land Use and Land Management

The majority of the suite is undeveloped and lies within the Waipunga State Forest, the Kaimanawa State Forest Park or is unoccupied crown land. Exotic forestry has increased since the time of the survey. The main area is at the head of the Waipunga and Hautapu catchments, and is part of the Kaingaroa State Forest. A small area also occurs at the head of the Taharua catchment and is part of Waimihia State Forest.

Pastoral farming is limited to the easier slopes adjacent to the river terraces where tussock and manuka have been converted to grassland. On Poronui Station an area is being developed for agroforestry. Occasional fodder crops may be grown on the easier slopes.

Because of the potential for gully erosion that exists if the lapilli is exposed, soil conservation measures are important to minimise surface disturbance and prevent concentration of water. On pastoral land, maintenance of a complete pasture cover is important to prevent the development of sheet and rill erosion. Where cropping is carried out this should be done by contour cultivation. Gullies, ephemeral watercourses and seepage zones should be planted with trees or in some cases retired. Farm tracks and fences should be carefully sited to minimise soil disturbance and reduce stock concentrations. Likewise for forestry operations, logging tracks should be carefully sited and maintained, and concentration of water should be avoided. In the steepest areas erosion control forestry is a more suitable land use.

Land Use Capability Units

The 3 LUC units in this suite are defined on the basis of slope, and hence erosion potential. They occupy a position in the landscape between the river teraces formed from Taupo flow tephra and the steep greywacke hills and mountains which have only a shallow layer of airfall tephra. IVe3, VIel5 and VIIel9 are mapped on the intermediate slopes where the tephra cover is deep. There is a general pattern whereby IVe3 is mapped on the rolling slopes flanking the terraces and as the hills rise and slope angle increases VIel5, and finally VIIel9, are mapped.

Vile 19 was added to the Northern Hawke's Bay LUC classification towards the end of the survey, after LUC units had been numbered in capability order and the first worksheets had been printed. For this reason it could not be ranked correctly and was simply added after the lowest ranking Vile. A more appropriate ranking would be after Vllel 1.

LUC unit IVe3 (1170 ha)—Figure 86

Because IVe3 occurs on the margins of river terraces it is in more accesssible locations than the other two LUC units. This, together with the generally rolling nature of the topography, has meant that IVe3 is the most developed of the 3 LUC units in the suite. Exotic forestry is by far the major use, with some small undeveloped areas covered with scrub. Very little is used for grazing.

This is a marginal cropping unit from the point of view of erosion potential, soil and climate, and is best suited to occasional root and green fodder crops. Windbreaks and contour cultivation are necessary for cropping.

The erosion potential under grass is for slight to moderate gully, although present erosion has been recorded as negligible to slight in approximately equal proportions. Under cultivation the erosion potential increases to severe sheet, rill and gully and moderate wind.

The potential production figures give a site index for *P. radiataoi* 25-30 m and a stock carrying capacity of 11 su/ha.

LUC unit VIelS (10,120 ha)—Figures 86, 87

Strongly rolling to moderately steep slopes are unsuitable for cropping and here the unit mapped is VIel 5. With the increase in slope the erosion hazard also increases, and there is a potential for moderate to severe gully and moderate sheet erosion. Despite this potential, erosion was only recorded on 23% of VIel5, and was normally of only slight severity. This is because most of the unit has an indigenous forest or scrub cover. Any development of these areas to pasture will lead to an increase in erosion. Soil conservation measures should be an integral part of development on this unit. However because of the erosion hazard exotic forestry is considered a more suitable use for VIel 5. Potential production figures are similar to those of IVe3.

LUC unit VIIel9 (5250 ha)—Figures 87, 90

VIIel9 is mapped where slopes increase to moderately steep to steep. These hills have generally longer slopes and occur above VIel5, often including hill crests. On these slopes there is still a sufficient depth of Waimihia Lapilli for gully erosion to develop, and because of the increased slope there is a potential for severe gully and sheet erosion.

On slopes steeper than these the depth of both Waimihia Lapilli and the overlying Taupo Pumice decreases significantly and the underlying greywacke is much closer to the surface. On these slopes debris avalanche, soil slip and ultimately scree erosion occur. Such areas are mapped as VIIe7 or VIIIe5 and are part of LUC suite 15.

At the time of mapping 85% of the unit had a dominant scrub cover, 11% was indigenous forest and 4% was developed to pasture. If this unit is to be developed, exotic forestry would be the most sutable use. The potential for exotic forestry, with a site index for *P. radiata* of 23-28 m, is only marginally lower than for the previous two LUC units. Potential stock carrying capacity is 11 su/ha.

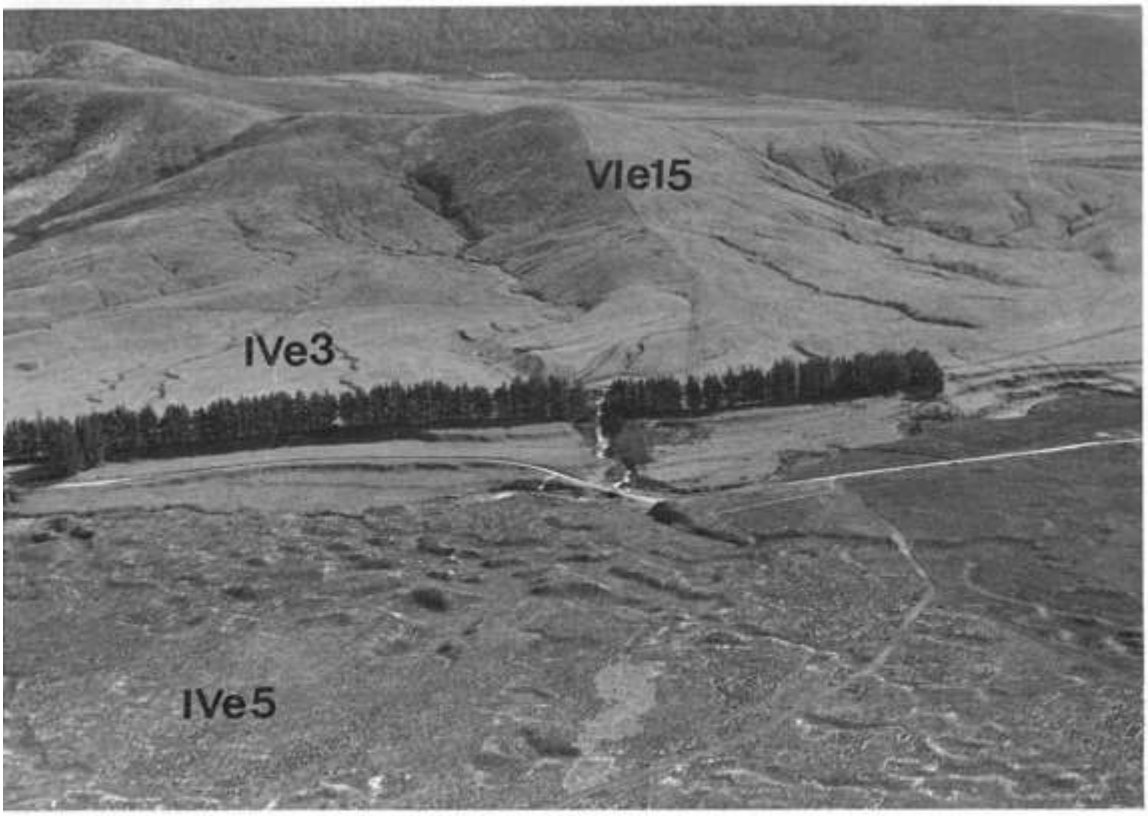


Figure 86: IVe3 in centre. Poronui Station, south-west of Rangitaiki. VIe15 hills behind. N103/733075, looking west. IVe5 in foreground (LUC suite 14).

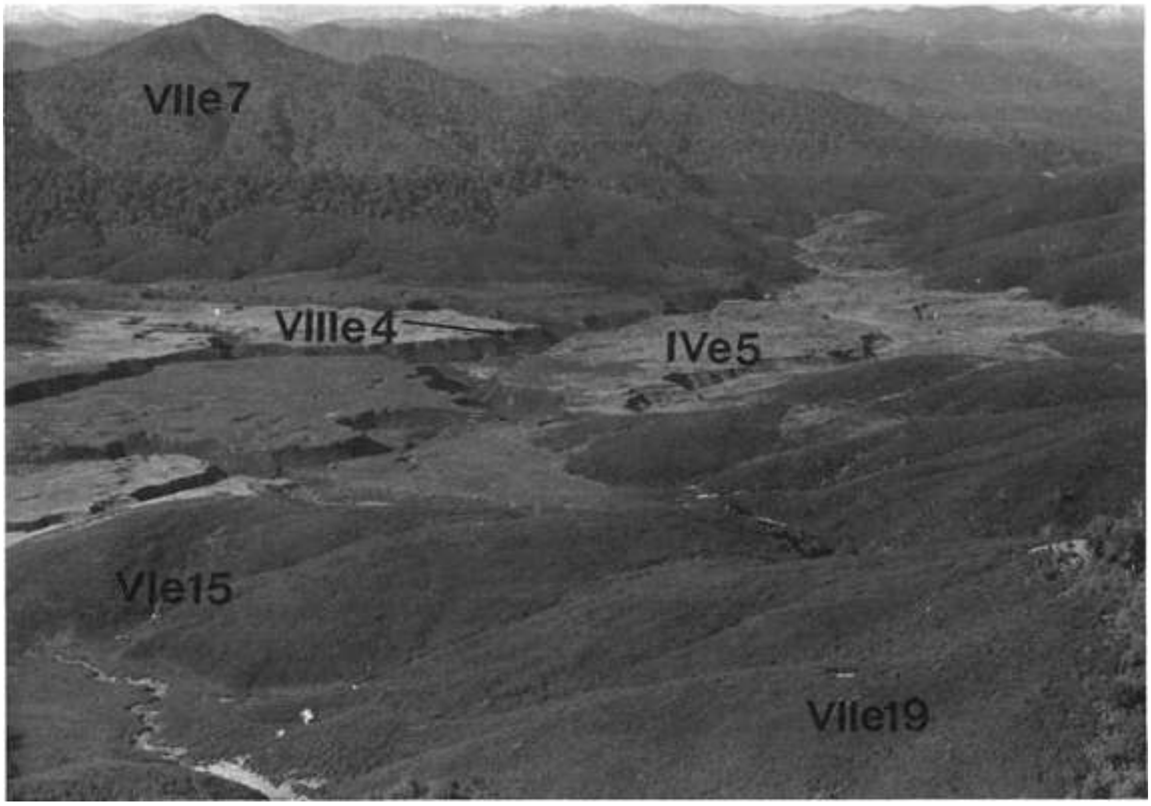


Figure 87: Vie 15 (low hills) in headwaters of Okoeke Stream, west of Pohokura. N104/920030, looking north. VIIel9 in foreground. IVe5 and VIIIe4 (gorges) in centre (LUC suite 14) and VIIe7 in background (LUC suite 15).

LUC SUITE 14: TERRACES FORMED FROM TAUPO FLOW TEPHRA AND VOLCANIC ALLUVIUM

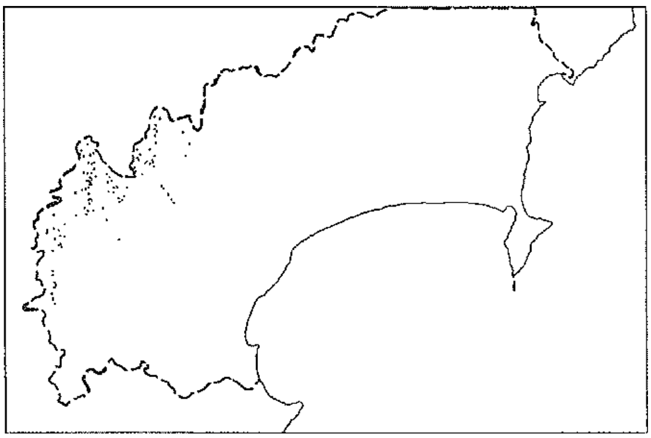
During the most recent eruptions from the Taupo Volcanic Centre (c. 1850 yr B.P.) a significant amount of tephra was deposited by nuees ardentes or glowing avalanches which consisted of incandescent clouds of gas and volcanic ash which flowed rapidly over the land surface for considerable distances and infilled low lying areas. Tephra with this method of deposition is referred to as "flow tephra" (Rijkse 1974d). Where both flow and airfall tephra have been eroded and redeposited by water this material is referred to as "water-sorted tephra" (volcanic alluvium). In addition to being sorted this material is generally finer than the flow tephra because of the addition of airfall material and because of abrasion during transport.

Both flow tephra and water-sorted tephra have infilled valleys to form plains and terraces which have subsequently been dissected. These plains and terraces are mapped using 4 LUC units which are defined according to the degree of dissection that has taken place. They occur in the headwaters of the following rivers; Taruarau, Ngaruroro, Mohaka, Taharua, Ripia, Waipunga and Hautapu (Figure 88).

Erosion is the major constraint to land use, however a harsh climate and poor soils are additional limitations. Character-istic erosion types are gully, streambank, sheet and wind.

The suite covers 16,960 ha (1.5% of the Region), but correlates to a much larger area of flow tephra and water-sorted tephra in the adjacent Bay of Plenty-Volcanic Plateau Region.

FLOH TEPHRf1



KM. 0 20 40 60 80 100 120 140 160 180 200
MILES 0 20 40 60 80 100 120
SCALE 1: 2000000 RESOLUTION: 0.5 MM
FRAME 1 ACROSS 1 DOWN. ORIGIN 345000 310000
DATA FROM NWASCO NZ LAND RESOURCE INVENTORY USING LAOEDA

Figure 88: Location of LUC suite on terraces formed from Taupo flow tephra and volcanic alluvium.

Climate

The climate is severe and has a significant effect on land use. However climatic information in this area is sparse. The nearest climatological station is at Waimihia Forest (760 m a.s.l.) which is on the Upper Rangitaiki Plains, whereas areas in this suite occur in valleys surrounded by hills or mountains of the main ranges. Rainfall is high, at between 1600 and 3000 mm p.a. (with most areas between 2000 and 3000 mm p.a.). At an altitude of between 700 and 1000 m a.s.l. temperatures are cold in winter. At Waimihia Forest there is an average of 118 ground frosts and 4 days of snow per year. These averages are likely to be considerably higher for the areas of the suite. Frost is not only a limitation to plant growth but it also assists wind and sheet erosion by dislodging and lifting soil particles where surfaces are bare. Because of the poor moisture holding capacity of the soil even short periods without rain soon lead to droughts.

Rock Type

The rock types in this suite consist of Taupo flow tephra [or Taupo Ignimbrite (Froggatt 1981)] which is part of the Taupo Pumice Formation, and Taupo water-sorted tephra which is the result of re-deposition of flow tephra and airfall tephra. No attempt was made to separate these two deposits and they have both been mapped as Tp, and occur within the same LUC units. This is because of the difficulty of field recognition, because of frequent over-lapping of the two deposits and because there appear to be no significant differences in erosion types or potential. However there are some differences in soil properties between the two deposits. At a more detailed scale than 1:63,360 flow tephra should be separated from water-sorted tephra. Deposits close to source (i.e., towards the head of a catchment) are more likely to be flow tephra, while deposits further from source are more likely to be water-sorted.

Taupo flow tephra consists of a poorly sorted rhyolitic breccia. It is loosely consolidated with grain size varying from ash to lapilli to block, and is coarsest nearest to source. It also contains numerous pieces of charcoal and burnt logs, which are the remains of the vegetation that was overwhelmed by the nuees ardentes.

Taupo water-sorted tephra has been better sorted during the course of its redeposition by water and consists of more uniform and finer grained ash-sized material.

Both the flow and water-sorted tephra are weakly weathered to unweathered.

Soils

Soils developed on these tephra are classified as yellow-brown pumice soils. They are coarse textured, have poor profile development and have compact subsoils. Although the soils developed on water-sorted tephra are the more productive, all soils in this suite have low natural fertility and are excessively drained.

The main soil types are Otamatea gravelly sand and Kaingaroa sand, but small areas of Otamatea sand and Poronui sand have also been mapped. Ninety two percent of the suite was mapped using soils from the Taupo County Survey (Rijkse in prep.) and the remaining 8% (in the Taruarau catchment) was mapped using soils from the Rangitikei County Survey (Campbell 1979).

Topography

When the flow and water-sorted tephra were originally deposited they formed plains and terraces with flat uniform surfaces. Due to the unconsolidated nature of these deposits they were soon dissected by streams, and this process is continuing today. The present degree of dissection varies with location, from the relatively wide, flat plains with few surface irregularities or dissections at the head of the Taharua River on the southern boundary of the Upper Rangitaiki Plains, to the narrow, closely dissected terraces at the head of the Ripia River. These narrow terraces occur at various heights, and may be up to 60 m above river level. They have numerous shallow ephemeral watercourses and other surface irregularities in addition to the streams that have cut down through the terraces. These dissections have near vertical walls, and are in many cases acting as a gully with both lateral and headward erosion occurring. The major rivers meander across a narrow flood plain below the level of these terrace surfaces.

This degree of dissection is the basis for defining the LUC units in the suite. With increasing dissection there is an increase in the potential for erosion and a decrease in accessibility which in turn restricts use.

Erosion

The present configuration of the terraces is the result of erosion. The coarse, unconsolidated parent material is particularly susceptible to removal by water, and gully and streambank are the major erosion types. Sheet and wind erosion are also significant, particularly on terrace surfaces.

Gullies may be initiated by streambank erosion or bank collapses along the margins of terraces, but are more commonly the result of headward migration of stream courses (Figure 104). The gullies that form are long, narrow and somewhat sinuous. The result is a dissected surface which, because of these dissections has an increased potential for further gully erosion. Not all of these dissections or entrenched watercourses are actively eroding, many have stabilised and revegetated naturally. However disturbance of the vegetative cover or concentration of water can soon lead to renewed gully erosion. The potential for gully erosion varies from slight to very severe.

Bare ground will also lead to frost lift which increases the rate of particle removal by wind and sheet erosion. Areas that are cultivated are particularly susceptible to wind and sheet erosion.

Vegetation

The natural vegetation of these terraces and plains is a combination of tussock associations and *Dracophyllum.* In the Waipunga and Hautapu catchments this is *Dracophyllum* and silver tussock. At the heads of the Taharua, Ripia and Mohaka catchments the natural vegetation is also silver tussock and *Dracophyllum,* while further down the valleys hard tussock becomes common. Manuka and kanuka are also present—the result of burning during the last 100 years (Hill 1911). In the Taruarau and Ngaruroro catchments the vegetation is red tussock and *Dracophyllum.*

In the Taruarau and Ngaruroro catchments the natural vegetation, although somewhat modified by animals and burning, is still present. However in the Taharua and Ripia catchments much of these tussock and *Dracophyllum* communities have been converted to pasture, and in the Waipunga and Hautapu catchments to exotic forest. The area of pasture (a mixture of introduced grasses and silver tussock) occurs on the more accessible plains and less dissected terraces.

Several small areas of lowland beech forest occur at the head of Mohaka River.

Land Use and Land Management

Much of the suite is on private, Maori or unoccupied crown land, although small areas occur within the Kaimanawa and Kaweka State Forest Parks and the Waipunga and Kaingaroa State Forests.

At the time of the survey 25% of the suite had been developed for pastoral farming with the remainder undeveloped. Pastoral farming is confined to the Taharua catchment and has increased in area during the last 10 years. Exotic forestry has become established on the terraces of the Waipunga and Hautapu Rivers.

Further development is possible, although because of the risk of gully erosion care should be taken to prevent concentration of water (Figure 102) and to maintain a vegetative cover in the ephemeral watercourses. Contour cultivation and the establishment of windbreaks are recommended on arable land. Gullies and permanent watercourses should be retired and planted with trees. In the case of actively eroding gullies, flumes should be constructed to carry water beyond the gully head and so prevent further scouring. On the more dissected terraces forestry is the most suitable land use as it performs an erosion control function. Areas in the Taruarau and Ngaruroro catchments, because of a combination of erosion potential and harsh climate, are best left undeveloped.

Land Use Capability Units

The LUC units in this suite range from class IV to class VIII and are defined on the degree of dissection, from areas that are wide and flat with no significant dissection to areas that are close and deeply dissected (Figure 89). Although there are wide, flat and stable plains, the nature of the parent material and the climate prevent these areas from being mapped as class III. No class VI was mapped, however at more detailed scales such areas could be identified. Likewise small areas of class VIII will occur within the dissections in all LUC units.

LUC unit IVs2 (3,840 **ha)—**Figure 91

IVs2 is the first LUC unit in the sequence. It is mapped on wide flat plains with little or no dissection. Unlike the other LUC units in the suite erosion is not a major problem. Under a continuous vegetation cover there is only a negligible to slight erosion potential, while under cultivation this can increase to a moderate potential. The erosion types are sheet, wind and gully.

In this LUC unit the major limitations to use are related to soil properties. These include poor soil structure, poor moisture-holding capacity and low nutrient status. Cropping is limited by a combination of soil and climate to root and green fodder crops and lucerne. The potential stock carrying capacity is 15 su/ha and the site index for *P. radiata* is 25-30 m.

IVs2 occurs only at the head of the Taharua and Waipunga catchments and is continuous with the Upper Rangitaiki Plains. Because of easy access it has undergone the most development of the LUC units in this suite.

LUC unit IVeS (4,980 **ha)—**Figures 86, 87, 90

IVe5 is mapped on narrow, flat to undulating terraces where there are only occasional shallow watercourses which dissect the surface. The number and depth of these dissections does not prevent cultivation but it does increase the erosion potential. These terraces are subject to runoff from surrounding hills which adds to the risk of gully erosion. When cultivated there is a severe potential for gully and a moderate potential for sheet and wind erosion. Although the soil and climate limitations are the same as for IVs2, the increased erosion potential is now regarded as the major limitation.

Care is required in siting tracks, fences and troughs to reduce stock-induced erosion. Ephemeral watercourses should be grassed and gullies retired. Contour cultivation and the establishment of windbreaks should accompany any cropping. The increase in the amount of dissection has no significant effect on productivity and the potential stock and forestry figures are the same as for IVs2.

IVe5 is more extensive than IVs2 and occurs in the head of the Taharua, Ripia, Mohaka and Waipunga catchments. Like IVs2 it occurs below an altitude of 850 m.

LUC unit VIIel6 (1,870 **ha)—**Figures 90, 94

Where the degree of dissection increases to the stage where cropping is precluded and the erosion potential is severe to very severe the terraces are mapped as Vile 16. They are deeply and closely dissected making access difficult. These terraces often border the major rivers and are particularly susceptible to streambank and gully erosion. Vile 16 occurs in association with IVs2 and IVe5, but also occurs in the Upper Taruarau and Ngaruruoro catchments where, because of the altitude (850-1000 m), all terraces are mapped as VIIel6 or VIIIe4. At this altitude bare ground is particularly susceptible to frost lift.

The soil conservation measures, as in the previous LUC units, are aimed at gully control and prevention, and reducing areas of bare ground. All gullies, active or otherwise, should be retired, and burning of the vegetation should be avoided.

The intensity of dissection has reduced the productive area of these terraces and the potential stock carrying capacity is only 12 su/ha, while the terraces are now unsuitable for production forestry. Most of the unit is undeveloped with a cover of tussock and *Dracophyllum.*

LUC unit VIIIe4 (6,270 **ha)—**Figures 87, 91

VIIIe4 is mapped where the potential for erosion makes safe use impractical. It includes terraces with a greater intensity of dissection than Vllel6, and also the river beds and lowest terraces of the major rivers. Gully and streambank are the major erosion types although there is also a potential for sheet and wind erosion if the vegetation cover is removed.

The unit is almost entirely undeveloped and it is recommended that the present tussock and scrub cover should be maintained.

i¥s2 IVe5 ¥lie1© ¥HSe 4

Slope		3G, 2Sh, **2W**	**A,B**	A + G
		(when **cultivated)**		
Eroclon Potential	2Sh, **2 W,** 2G **(when** cultivated)		4G, **3Sh, 3W**	4G, 4SSs, 2Shs **2W**
Potential Land Uoo	Grazing, Prociwetioti Focooiry, Fodder Cropping	Grazing, PsoducSSon Forestry, Fodder Cropping	Grazing	Protection Grassland

Increasing slope, altitude and degree of dissection

Figure 89: Relationship between LUC units on terraces formed from Taupo flow tephra and volcanic alluvium.

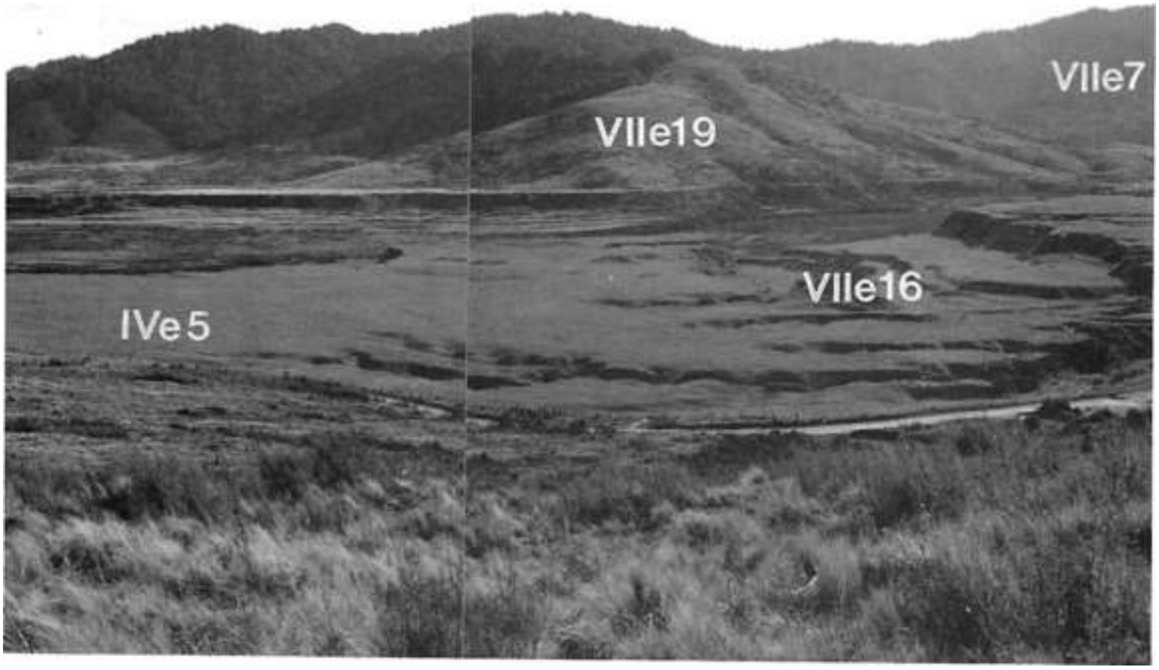


Figure 90: Vile 16 Poronui Station, south-west of Rangitaiki. Nl 13/740940, looking south-west IVe5 in left centre. Vile 19 hills in centre (LUC suite 13), VIIe7 range in background (LUC suite 15).

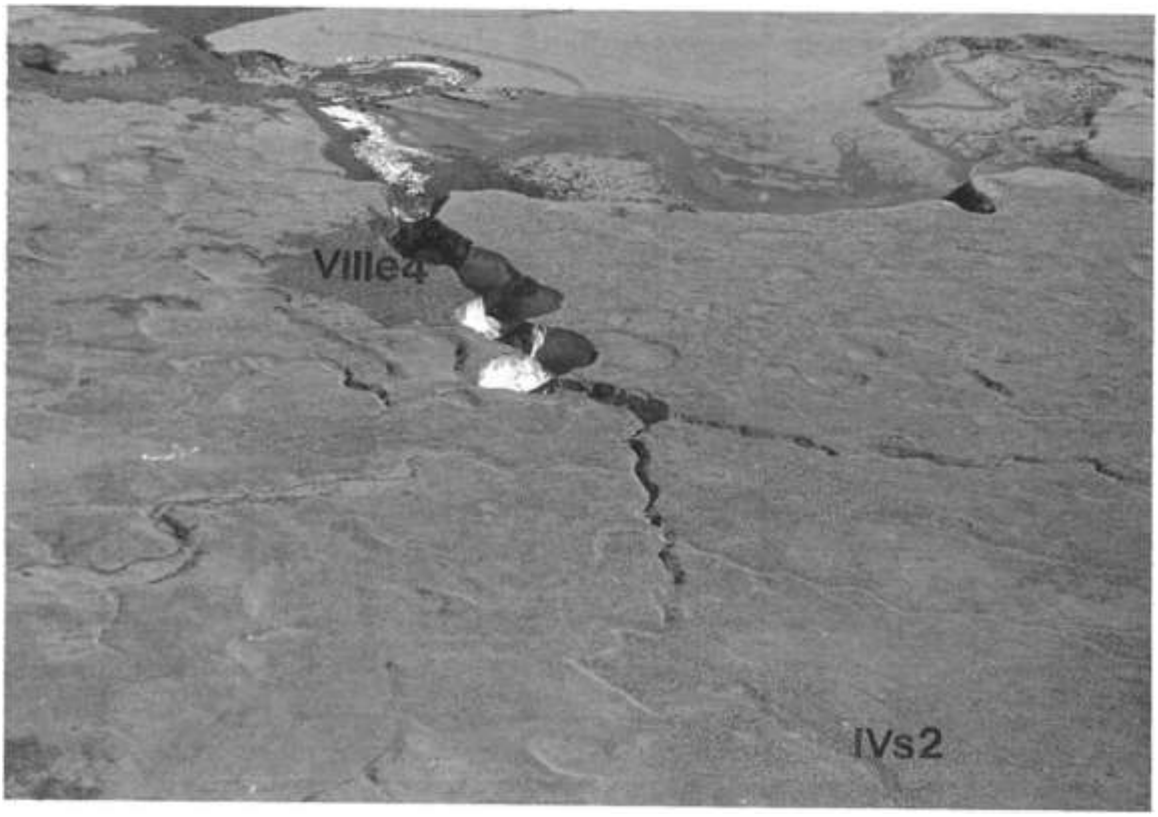


Figure 91: VIIIe4. Poronui Station, south-west of Rangitaiki. N103/750085, looking south-west. IVs2 in foreground.

LUC SUITE 15: GREYWACKE MOUNTAIN AND HILL COUNTRY WITH A MANTLE OF TAUPO AIRFALL TEPHRA

This is one of two suites mapped in the main axial ranges, along the western margin of the Region (see also LUC suite 16). It occurs in the Huiarau and Ahimanawa Ranges and the north-eastern Kaimanawa and northern Kaweka Ranges, together with a small area in the Ruahine Range near the southern boundary of the Region (Figure 92). These are areas of greywacke, which have a shallow mantle of tephra and where the vegetation is largely indigenous forest. Small areas of scrub, pasture and exotic forest do exist, although these tend to be on the less steep, lower altitude hills on the margin of the main ranges.

Land use within this suite is severely limited by the climate, steep rugged slopes and the potential for erosion. Of these erosion is regarded as the major limitation. Although of very limited productive value, the suite is an important one, its major role being that of catchment protection. LUC units within the suite are defined on the basis of slope and altitude, and there is a strong relationship between these factors and the potential erosion severity. There are 5 LUC units in the suite which occupy 16% of the Region. With a total of 183,870 ha this suite is the second largest in the Northern Hawke's Bay Region.

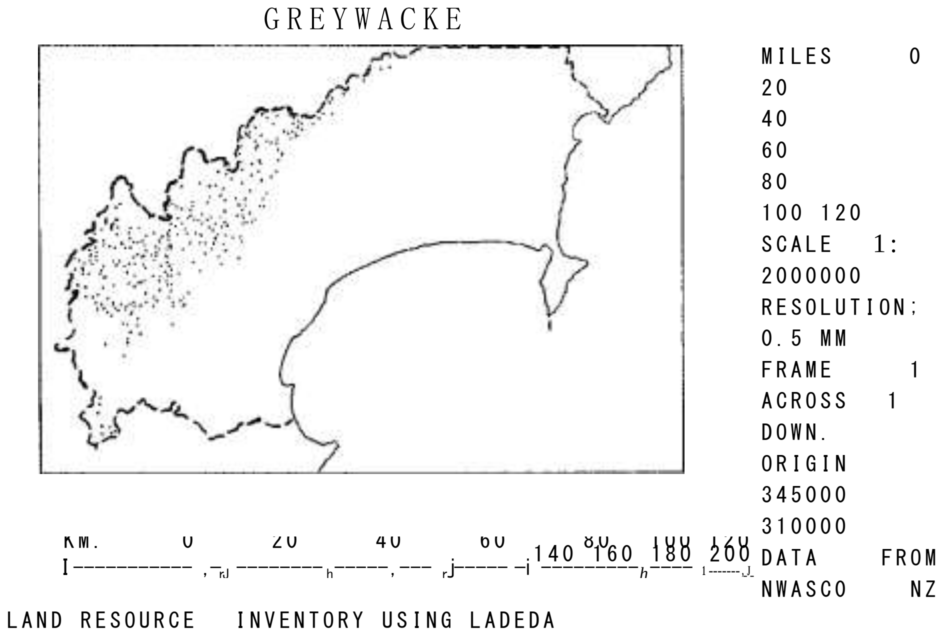


Figure 92: Location of LUC suite on greywacke mountain and hill country with a mantle of Taupo airfall tephra.

The essential differences between this suite and LUC suite 16 are the vegetative cover and erosion status. In this suite the indigenous forest is largely intact. Developed areas are limited and occur at low altitudes where the climate is comparatively mild. As a result erosion is characterised by debris avalanche and soil slip with minor scree. However in LUC suite 16 the vegetation is highly modified. Forest is only a small component of the present cover, and has largely been replaced by scrub and tussock. Although it is unclear as to the exact history, the present vegetation pattern appears to be the result of a combination of natural, Maori and European fires.

Climatic events (Grant 1963) and introduced animals (Cunningham 1974) have also been implicated in these changes. This destruction of the original forest cover has exposed the tephra and underlying rocks to a montane climate which has resulted in extensive and spectacular sheet, wind, scree and gully erosion.

These two mountainland suites have different histories of land use, different vegetation and erosion status and therefore have different soil conservation and water management requirements. However the parent materials, topography and climate of both suites appear to be essentially the same. It is a matter of conjecture as to whether the presently forested areas in this suite would, with the same history, resemble the highly eroded suite.

Climate

The climate of much of the suite is montane, and this is one of the main factors which limits land use. The suite varies in altitude from 250 m a.s.l. along the Mohaka River to 1450 m a.s.l. in the Kaweka Range. The rainfall is related to altitude and topography and ranges from 1500 to 3000 mm p.a. Although there is a winter maximum, rainfall is high throughout the year.

Climatic data is scarce for this suite, and must be extrapolated from the nearest climatological stations, which are usually on the margins of the suite. Summers are generally cool and winters cold. The mean annual temperature at Onepoto, Lake Waikaremoana (600 m a.s.l.) is 11.1°C.

Little information is available on wind, although it would appear wind intensities vary considerably according to location, from sheltered valleys to exposed ridges. The occurrence of snow and frost increase with altitude, and although snow is generally rare, frosts are common. At Onepoto ground frosts average 38 days/year, however the average is much higher for most of the suite.

Rock Type

The major unifying feature of this suite is the rock type. This is greywacke of Mesozoic age which is part of the Torlesse Supergroup (Suggate 1978). The term 'greywacke' is used here to describe indurated sandstones, siltstones and mudstones which are interbedded and deformed. In this Region greywacke is divided into 3 units. The most indurated and deformed unit, Kaimanawa Greywacke occurs furthest west in the Upper Ngaruroro catchment. Induration and deformation decreases eastwards through the Kaweka Greywacke of the Kaweka and Ahimanawa Ranges to the Urewera Greywacke of the Huiarau and Northern Ruahine Ranges. Age is assumed to increase from east to west with the Kaimanawa Greywacke being less erodible than the other two. Greywacke is the oldest rock type in the Region.

Because of the relative proximity to the volcanic centres of the central North Island the greywacke, even on the steepest slopes, has a tephra cover. This may be in excess of 2 m in the west. Only on the steepest slopes in the east is tephra too thin to be recorded as a rock type. Tephra however is absent wherever erosion has occurred.

The tephra cover consists of a number of different deposits. "Mo" ashes overlie the greywacke and consist of Rotorua Sub-group tephras in the north and Tongariro Sub-group tephras in the south. A layer of Waimihia Lapilli overlies these ashes. Above this layer is Taupo Pumice which, except in the north-western part of the suite, forms the uppermost deposit. In the north-west, north of Lake Waikaremoana, a shallow layer of Kaharoa Ash overlies Taupo Pumice.

Soils

Soils in this suite are podzolised and are either yellow-brown pumice soils in the north or composite yellow-brown pumice soils on yellow-brown loams in the south, depending on the depth of the various tephras. The majority are steepland soils, although some hill soils occur on slopes below 26°. The most extensive are Urewera steepland soils which are mapped throughout the Huiarau and Ahimanawa Ranges and in the northern Kaweka Range. The soils of much of the remaining southern area are mapped as Kaweka steepland soils. The main hill soils are Matawai in the north and Makahu in the south.

Soils of the suite are mapped using 5 soil surveys. The Taupo County Survey (Rijkse in prep.) covers 51.8% of the suite, the Wairoa County Survey (Rijkse unpublished) covers 30.4% of the suite, 10.2% is covered by the Mid Hawke's Bay Survey (Pohlen *et al.* 1947), 5.9% by the General Survey (New Zealand Soil Bureau 1954) and 1.6% by the Rangitikei County Survey (Campbell 1979).

Topography

This suite, together with parts of LUC suite 16, contains the steepest most rugged terrain in the Region. Apart from some foot hills, the majority of the suite consists of mountain ranges. Slopes are generally long and steep to very steep, with many in excess of 40°. The terrain is closely dissected with narrow ridges and in places rivers have entrenched to form gorges.

Erosion

Unlike the other mountainland suite, erosion in this suite is not extensive and is generally of only slight to moderate severity. However this is mainly due to the presence of an indigenous forest cover. If this was significantly altered the potential exists for erosion of a similar magnitude to that occurring in the other mountainland suite.

The major erosion type is debris avalanche, with scree, soil slip, sheet and gully also occurring. In areas of indigenous forest much of this erosion is the result of storms and can be regarded as natural. However introduced animals such as deer, goats, pigs and possums are also a contributing factor.

Debris avalanches occur on steep forested slopes and are rapid flows or slides which scour a narrow track through the vegetation, removing the regolith. The speed of movement and weight of debris normally ensures that a debris avalanche continues until it reaches the base of the slope where the debris enters a stream, often chocking the channel. This debris will then be washed away during this storm or a later storm. The scar is often subsequently eroded further by sheet, rill or gully erosion (Eyles 1985), which may lead to the development of scree erosion.

Despite this, revegetation of the scar is normally rapid, initially by herbaceous plants, then followed by scrub species. The return to a forest structure however takes much longer. The history of erosion can therefore be interpreted from the successional patterns of the vegetation.

Soil slip and sheet erosion are more common in areas with a cover of pasture or scrub, and on the steeper slopes where soils are shallow and the greywacke is near the surface, scree erosion may also develop.

Vegetation

Of all the suites in the Region the vegetation in this suite is the least modified. Eighty three percent of the vegetation is indigenous forest with the remainder consisting mainly of manuka, fern and mixed indigenous scrub. Only very limited areas of pasture and exotic forest occur, although the area of exotic forest has recently increased at the expense of scrub and fern. The areas of pasture, scrub and exotic forest are confined to the class VI and VII units which flank the main ranges.

The indigenous forests include both lowland and mid-altitude podocarp-hardwood forest and lowland and highland beech forest. Their distribution is largely altitudinally controlled, although much of the forest in the Ahimanawa Range and the south-western part of the Huiarau Range has been modified by volcanic activity. Lowland podocarp-hardwood forest occurs below approximately 850 m a.s.l. with lowland beech forest occurring mainly between 750 and 1050 m a.s.l. In many areas between these two major forest classes is a zone (600-850 m a.s.l.) where podocarps and hardwoods are admixed with beech. Much of the lowland podocarp-hardwood forest has been logged and in several areas logging is being carried out at present. Highland beech forest and the less common mid-altitude podocarp-hardwood forest both occur between 900 m a.s.l. and the timber line. The mid-altitude podocarp-hardwood forests are confined to areas near the Napier-Taupo Road at an altitude where elsewhere beech forest is present. The reason for this is likely to be destruction of beech forest due to volcanic activity and its replacement by more rapidly colonising podocarps and hardwoods. On several high points above 1350 m a.s.l. sub-alpine scrub is found. This is a leatherwood dominated scrub with some stunted mountain beech, pink pine and mountain toatoa. The pattern of the forests of the Urewera area have been described by McKelvey (1973).

Land Use and Land Management

Although land use in this suite has been minimal, sensitivity to erosion means that land management is important.

As most of the easier hill country on the margins of the suite has already been developed, the potential for any further development is limited while the benefits are small and the risks great. The success of such development would be dependent on the appropriate land management. Even the class VIII land which has no productive potential and occupies 48.7% of the suite requires certain land management techniques to ensure that these areas are able to perform their soil conservation and water management functions adequately and so protect areas downstream.

Historically the main productive use has been extensive grazing and indigenous logging, however current trends indicate that exotic forestry will be the major use in the future. The largest area of grazing and exotic forestry is in the vicinity of the Napier-Taupo Road.

On areas where grazing is carried out, maintenance of a complete pasture cover is necessary to prevent erosion, particularly sheet and scree. A strict control of burning, which is necessary to control re-growth of scrub, is also important. Logging operations, both exotic and indigenous, should be designed in such a way as to minimise the erosion hazard. Noxious animals should also be controlled.

For the areas of indigenous forest the main use is recreational, the major activities being tramping, hunting, fishing, canoeing and rafting. Such activities are provided for by the Urewera National Park and the Kaweka, Kaimanawa and Ruahine State Forest Parks. Most of the remaining area is scattered throughout a number of State Forests, which also provide recreational opportunities.

Land Use Capability Units

This suite has only a limited productive potential. Of the 5 LUC units only Vie 12 has the potential for intensive use. For VIIe7 and Vile 15 potential stock carrying capacities are low and very low, and while the site index range for *P. radiata* is medium to low, erosion control forestry is necessary because of the potential for erosion. VIIIe5 and VIIIe6 have no productive potential.

In all cases erosion potential is the major limitation, although climate, slope and shallow low fertility soils are added restrictions.

LUC unit VIel2 (10,940 ha)—Figure 93

This LUC unit is mapped on moderately steep hill country where the tephra mantle is relatively deep (0.5->l m). The main soils are Matawai and Makahu hill soils although some steepland soils also occur. It forms the foothills of the main ranges or in some cases lower hills along valleys within the ranges. On the flanks of the ranges the vegetation is mainly manuka, bracken or low producing pasture (some of which is being converted to exotic forest), whereas within the ranges it is lowland podocarp-hardwood forest or beech forest. There is a large area between Tarawera and Te Haroto on the Napier-Taupo Road, much of which is being planted in *Pinus radiata.* This, together with the scrub and low producing pasture reflects the low natural fertility and reversion problems associated with the suite. The present average stock carrying capacity is only 5 su/ha with a potential of 9 su/ha, while the site index for *P. radiata* is 23-30 m. The wide site index range reflects the altitudinal variation within the LUC unit, from 600 to 1000 m a.s.l. Erosion potential is moderate with soil slip, sheet and scree being the main types.

LUC unit VIIe7 (82,200 ha)—Figures 87, 90, 94

As slope angle and slope length increase the layer of tephra becomes shallower and patchy in distribution, the steepest slopes with little or no tephra. The soils are also shallow and are mapped as Urewera steepland soils or Kaweka steepland soils. These changes together with an increase in altitude and annual rainfall leads to increased leaching of the soils and also an increased erosion potential. Rapid reversion to fern and scrub are also a problem. As a result of these increasing limitations to use these areas are mapped as VIIe7. The potential for soil slip and scree erosion is now severe, although as most of the unit is in indigenous forest or scrub, present erosion is usually only slight. A moderate gully and sheet erosion potential also exists. Present average carrying capacity is very low at 2 su/ha with a potential of 7 su/ha. Site index for *P. radiata* is 20-29 m, again dependent on altitude.

Like the areas of class VIII, an important function of VIIe7 is soil conservation and water management.

LUC unit VllelS (1,140 ha)—Figure 95

This LUC unit is not strictly part of the greywacke sequence, although the rocks are of similar age. It is restricted to two small areas, one where the Waipunga River joins the Mohaka River and the other where the Hautapu river joins the Te Hoe River. The unit is characterised by steep hill slopes with large eroding amphitheatre-like gullies which contribute large amounts of debris to streams. The parent material is argillite and greywacke associated with crush zones. This unit has affinities with the gullied argillite hill country of Mangatu and Ruatoria north of Gisborne, and Awhea in the Wairarapa.

The Hautapu-Te Floe area is presently in manuka but has developed moderate gully erosion. The area along the Mohaka River has severe gully and scree erosion and has recently been planted in exotic forest. The potential for gully erosion on this LUC unit is very severe to extreme and it is best left undeveloped or, if erosion has reached an advanced stage, should be used for erosion control forestry. Site index for *P. radiata* is 26-29 m. The potential stock carrying capacity is only 4 su/ha.

LUC unit VHIeS **(88,640 ha)—**Figure 96

VIIIe5 is confined to and comprises much of the main ranges. It is associated with VIIe7 and occurs where increases in slope length and slope angle, together with increases in altitude and annual rainfall lead to a very severe to extreme erosion potential and shallow, strongly podzolised soils. As a result this unit is unsuitable for productive use.

It is typically very steep forested mountainland where annual rainfall is between 2000 and 3000 mm p.a. The tephra layer, although largely undisturbed is very thin and patchy. The strongly podzolised soils are of low natural fertility.

Vegetation is almost entirely indigenous forest, with lowland beech forest being the most extensive forest class. Because of the relatively undisturbed nature of the forests, present erosion is only slight to moderate and consists mainly of debris avalanches, the result of high intensity storms. Noxious animals also have a deleterious effect on the vegetation which in turn affects the ability of the forests to act as a buffer against these high intensity rainstorms. Major disturbances such as removal of the forest would lead to very severe to extreme erosion.

Although the parent material is normally greywacke, in the vicinity of Lake Waikaremoana and at the head of the Ikawetea Stream in the northern Ruahine Range, VIIIe5 is also mapped on Tertiary sandstone and siltstone. This amounts to 6,760 ha and is described in LUC suite 11.

LUC unit VIIIe6 (950 ha)

A restricted area is mapped as VIIIe6 where present erosion is more serious than in the previous LUC unit. There is severe to very severe debris avalanche erosion with the potential for extreme erosion with forest removal. This unit identifies the areas of serious present erosion, but due to the nature of this survey, time did not allow a study into the causes. A range of factors may be involved, among them are the following: slopes that are steeper and/or at a higher altitude than those of VIIIe5, the presence of faults or crush zones, localised very high intensity rainstorms.

As with the previous LUC unit, VIIIe6 is also mapped on an area (2280 ha) of bedded sandstone and siltstone north of Lake Waikaremoana. This area is also described in LUC suite 11.

Figure 93: VIe12. Te Haroto, Napier-Taupo Road. N114/020840, looking west.

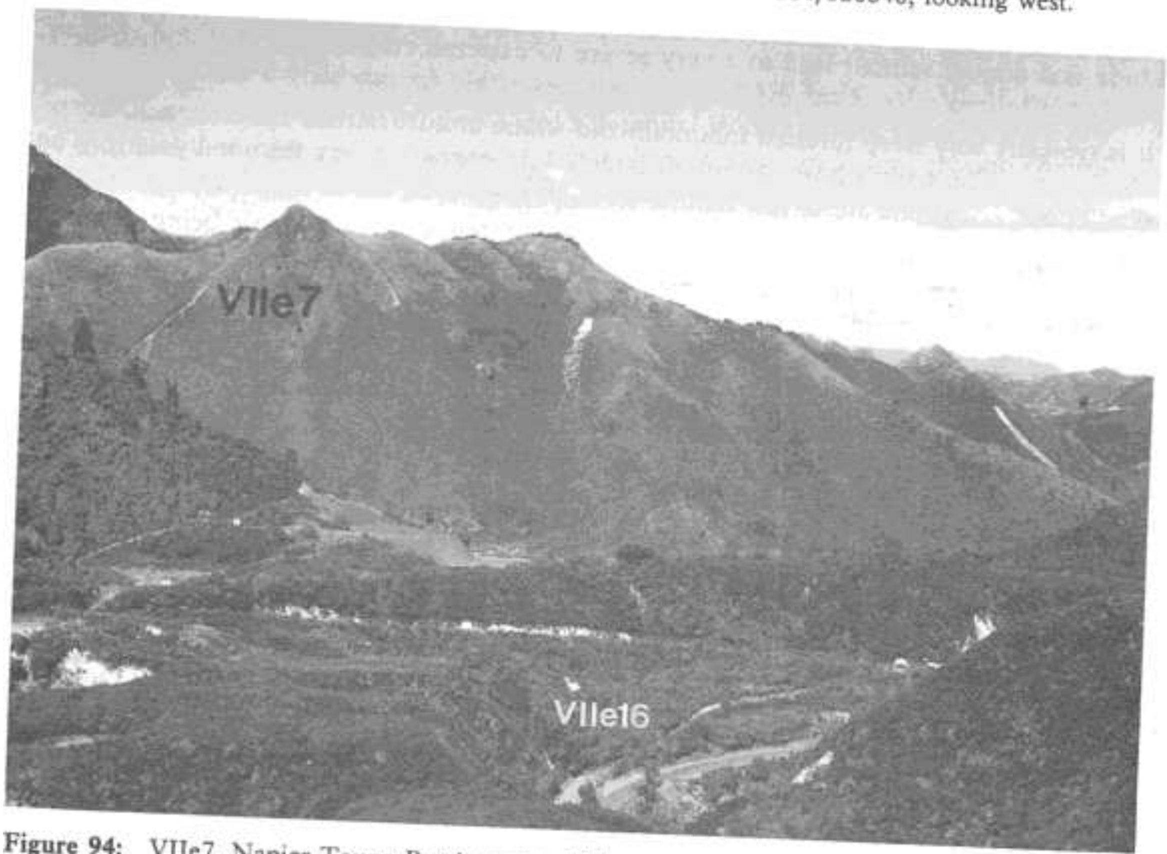


Figure 94: VIIe7. Napier-Taupo Road, north of Tarawera. N114/010975, looking south. VIIe16 in foreground (LUC suite 14).

Figure 95: VIIe15, Woodstock State Forest, Mohaka River. N114/145873, looking south-east. Photo: N A Trustrum

Figure 96: VIIIe5. Maungataniwha Trig, south-western boundary Urewera National Park. N104/240215, looking north-west. Photo: N A Trustrum

LUC SUITE 16: UPLANDS AND MOUNTAINLANDS WITH A MANTLE OF HIGHLY ERODIBLE TEPHRA

This suite is mapped in the Napier-Taihape Road area, from the Ngamatea Swamp in the west to 'The Blowhard' in the east, and from the headwaters of the Ngaruroro and Taruarau Rivers in the north to Lessong Monument in the Ruahine Range in the south, and includes the main Kaweka Range (Figure 97). It therefore includes both mountain ranges and upland plateaux and basins.

The features of this area which have a dominant effect on land use are: the harsh climate, a mantle of loose relatively coarse tephra, a large proportion of steep to very steep slopes and a history of burning and overgrazing which has dramatically affected the vegetation. The result is serious and widespread erosion. The area, although of very limited productive value is nevertheless an important one. It has value as a recreational area, but primarily its value lies in the fact that most of the area is drained by the Ngaruroro and Tutaekuri Rivers which flow across the Heretaunga Plains. The erosion and condition of the vegetation in these headwaters directly threaten the highly productive downstream areas through flooding and deposition. Expensive river control works have been essential.

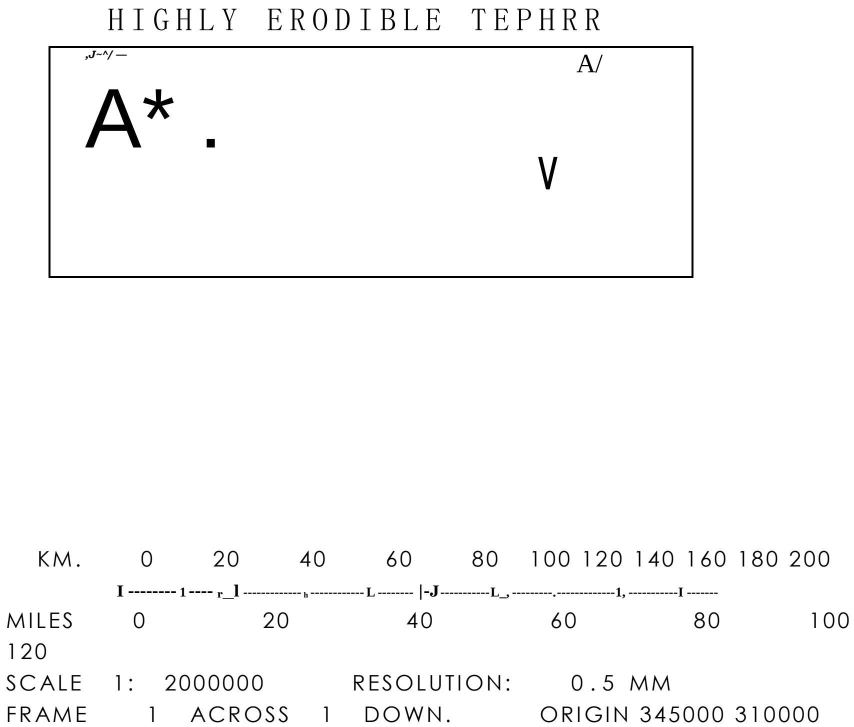


Figure 97: Location of LUC suite on uplands and mountainlands with a mantle of highly erodible tephra.

The LUC units in this suite are defined on the basis of slope, altitude and, where slopes are steep and the tephra mantle is shallow, underlying rock type. These factors dictate the type and severity of erosion that is present or may develop. Erosion is regarded as the major limitation on most of the LUC units in this suite, although climate is a limiting factor to use for all the LUC units. There are 11 LUC units in the suite with a total area of 106,350 ha, 50% of which has no productive potential (class VIII). The suite occupies 9.2% of the Region.

To the north and north-west of the upper Ngaruroro catchment there is a dramatic change in both the vegetative cover and erosion status. Here the vegetation is almost entirely beech forest, and erosion is only slight and confined to debris avalanches. Such areas are mapped within LUC suite 15 which extends north-west into the Huiarau Range. Valley systems in the upper Ngaruroro and Taruarau catchments have been infilled with coarse rhyolitic flow tephra [or Taupo Ignimbrite (Froggatt 1981)] which forms terraces which are mapped in LUC suite 14.

Climate

The climate is montane and as such has an important effect on land use, both as a limiting factor to plant growth and as a contributing factor to the severe erosion that has taken place. The relationship between climate and erosion will be discussed in the section on erosion.

In general the area centered on the Napier-Taihape Road and including the Kaweka Range has less rain and cloud than other North Island Ranges (Elder 1959). The rainfall is related to altitude and topography, with a wide range within the LUC suite, from about 1000 mm p.a. on the Ngamatea Plateau to 1600 mm p.a. at Kuripapango to in excess of 3600 mm p.a. on the crest of the Kaweka Range. Much of the class IV and VI land has a rainfall less than 2000 mm p.a. while the class VII and VIII land occurs over the whole rainfall range. The rainfall is fairly evenly spread throughout the year with the maximum in winter. Rainfall patterns for the Kaweka Range are described by Grant (1969).

The area is subject to strong winds, mainly north-westerlies and south-westerlies. At Makahu Saddle wind gusts in excess of 97 km/h have been recorded for every month of the year, and on occasions in excess of 129 km/h. Above 1200 m a.s.l. winds are thought to be considerably stronger. Only 2% of days are calm (Cunningham 1974).

Snow can occur during any month on the summit of the Kaweka Range and may lie for up to 5 months at altitudes above 1500 m. Cunningham (1974) records 40 days/year with snow lying at 900 m a.s.l., and 130 days/year with snow lying at 1500 m a.s.l. for the Tutaekuri catchment. At Kuripapango he records 78 days/year with ground frosts and at Makahu Saddle 121 days/year with ground frosts. Ngamatea Station records 143 frost days/year.

Rock Type

The area has been mantled by a series of ash showers from the vicinity of Lake Taupo to the west. Hence these deposits decrease in thickness from the north-west to the south-east, where they are practically absent. They are also shallow to absent on many steep slopes because of natural erosion, and on many steep and easier slopes because of accelerated erosion.

In the north-west, on and north of the Ngamatea Plateau, the uppermost deposit is a very shallow layer of Ngauruhoe Ash (Topping 1973). This is an unweathered, dark, loose andesitic ash very prone to erosion. It originates from the craters of Mounts Ruapehu and Ngauruhoe and has been deposited during the last 400 years. At this distance from source it is a fine-grained ash.

Over most of the area of the suite however, the uppermost deposit is Taupo Pumice which was deposited approximately 1850 yr B.P. (Healy *et al.* 1964), from a probable source in eastern Lake Taupo. Taupo Pumice overlies Waimihia Lapilli with an age of approximately 3400 yr B.P. (Healy *et al.* 1964). These two rhyolitic deposits are pumiceous in nature, consisting of yellow-brown to pale yellow, loose, coarse sand and lapilli. This material is easily eroded by wind and water and in many places has been completely removed to expose the underlying tephras. These range in age from 2500 to 20,000 yr B.P., are andesitic in nature and include Tongariro Ash and older ashes (Topping 1973). They are dark brown and more weathered and compact in nature than the overlying rhyolitic tephras, and are hence more resistant to erosion. In many places it is this layer that forms the surface, either as bare ground or with a cover of scrub. In areas where erosion is severe, particularly on steep slopes, even this layer has been removed to expose the underlying bedrock.

The underlying rock is usually greywacke of Mesozoic age, although there are significant areas of Tertiary rocks. The Tertiary rocks are mainly sandstones, limestones and conglomerates. The greywacke consists of alternating, indurated sandstone and mudstone, highly folded and fractured. It is divided, on the basis of age, into three units. Urewera greywacke occurs in the east and south. Kaweka greywacke occurs to the north of the Napier-Taihape Road, and in the east is separated from the Urewera greywacke by the Kaweka fault (along the base of the Kaweka Range). Kaimanawa greywacke occurs in the north-west, in the upper Ngaruroro catchment north of Panoko Stream (Grindley 1960). Urewera greywacke is the youngest, most highly folded and most erodible, while Kaimanawa greywacke is the oldest, least folded and least sensitive to erosion.

The Tertiary rocks overlie the greywacke and form three major blocks; the Ngamatea Plateau, the Timahanga Basin, and a series of plateaux and ridges extending from Kuripapango to the Kaweka Forest Headquarters. They are mainly Tongaporutuan-Kapitean in age (R Black pers. comm.). In the vicinity of 'The Blowhard' limestone forms a number of prominent north-south trending ridges which dip to the east.

Soils

The soils in this suite are developed on tephra, and range from yellow-brown pumice soils to composite yellow-brown pumice soils on yellow-brown loams, to yellow-brown loams depending on the type and depth of tephra. Yellow-brown pumice soils occur mainly in the west and north where Taupo Pumice and Waimihia Lapilli have a combined depth of >50 cm. A small area of yellow-brown loams occurs in the south where these tephras are absent and the soil forming material consists of older more weathered tephra (Tongariro Ash). Where the depth of Taupo Pumice and Waimihia Lapilli is <50 cm soils are composite yellow-brown pumice soils on yellow-brown loams. In the north where rainfall is high and altitudes are in excess of 600 m the soils are podzolised. Taruarau and Ngamatea soils are common on flat to hilly land and Kaweka and Urewera soils are common on steep and very steep land. Steepland soils occur on 71,250 ha of the suite.

Although quite different physical, mineralogical and chemical characteristics occur in the yellow-brown pumice soils and yellow-brown loams, these differences are superseded by climate and erosion, which are the major influences on land use and land management.

The area over which the suite extends is covered by 4 soil surveys. The Mid Hawke's Bay Survey (Pohlen *et al.* 1947) covers 40.9% of the suite, 39.6% is covered by the Rangitikei County Survey (Campbell 1979), 13.3% by the Taupo County Survey (Rijkse in prep.) and 6.2% by the General Survey (New Zealand Soil Bureau 1954).

Topography

There is a wide range of slopes in this suite although the majority are steep to very steep. The topography varies from swamps to undulating and rolling plateaux and ridges, to very steep long mountain slopes. Four percent of slopes are flat to undulating, 20.5% are rolling to strongly rolling, 7% are moderately steep and 68.5% are steep to very steep. Generally the mountain slopes consist of greywacke while plateaux and low hills are formed of sandstone.

Erosion

Erosion is a dominant feature of LUC units in this suite. Although amongst the least productive areas in the Region it is the area of most severe erosion. The major erosion types are wind, sheet and scree. An erosion sequence begins when the vegetation is removed, principally by burning and grazing, to expose the soil. The structural properties of the soil are such that, once exposed to the harsh climate, it is rapidly eroded. Particles are removed by a combination of wind and sheet wash. This is enhanced by frost heave, whereby the freezing of soil water causes the separation of soil particles and their lifting at the surface by needle ice. On thawing the surface has a 'fluffy' loose appearance as a result of the physical separation of the soil particles. These particles are now susceptible to removal by wind and water. In this way both the soil and underlying tephra are removed. Taupo Pumice and Waimihia Lapilli are particularly susceptible to this process. The older more weathered andesitic tephra beneath is eroded in similar fashion but at a slower rate due to the finer texture, higher clay content and more compact nature of the material.

Because these bare surfaces are a result of a combination of wind and sheet wash, no attempt has been made when recording erosion to assess the relative contribution of the two processes. Rather, both erosion types are assessed as having the same severity, e.g., 4SH4W. This indicates that the erosion is very severe and consists of wind and sheet acting on the same surfaces. However sheet erosion will be more active on steep slopes than on flat to rolling slopes, and wind erosion will be less significant on surfaces sheltered from the prevailing wind.

Where the more weathered tephras have been removed the bedrock is exposed. Where this is sandstone a bare impervious surface is formed on which recolonisation by seedling plants is very difficult. Once the overlying tephras have been removed little sediment is added to streams from the underlying sandstone, but rate of runoff increases. In the case of greywacke, exposure of bedrock on steep slopes leads to scree erosion. This is also enhanced through the freeze and thaw action of water acting upon the jointed and fractured nature of the greywacke. Dislodged fragments of rock are then subject to downward movement or scree creep by the action of water, gravity or trampling by animals (including man). Once screes reach a watercourse they are continually undercut, which increases their rate of movement. Gully erosion is of localised significance. It occurs mainly on long steep greywacke slopes, and like the more severe areas of scree erosion, is associated with the type and attitude of the bedding, crush zones, and to a lesser extent faulting (Speden 1978). Debris avalanches and soil slips also occur on steep slopes.

Cunningham (1974) has studied the headwaters of the Tutaekuri catchment which drains the south-eastern side of the Kaweka Range and 'The Blowhard' area. He has made observations on the rate of erosion between 1960 and 1968. In summary, flat surfaces of Taupo Pumice were eroded at about 0.6 cm annually, and gentle slopes at 1.3 cm annually. On steep banks the annual rate was 4 cm for Taupo Pumice and 2.5 cm for weathered andesitic tephra. Near a seepage point a removal rate of 10 cm a year was recorded. Movement of most screes was observed as 'slow but constant'.

Observations from the 1880-90s indicated that the area around the Blowhard Plateau and the Kaweka Range was already severely eroded, and a photograph of the range taken in 1912 shows a remarkable similarity in the extent of erosion surfaces with the present day. It would seem that today erosion is continuing at a reduced rate, mainly by the extension of existing bare surfaces. Only a few new surfaces have developed. However colonisation of screes is slow and large quantities of shingle will continue to be supplied to rivers for the foreseeable future. Furthermore the potential for erosion is still high and further deterioration in the condition of the vegetation would undoubtably lead to an increase in the rates of erosion.

Vegetation

The vegetation forms a complex pattern which reflects the effects of both climate and a history of burning and grazing. Although at one time the area of forest would have been more extensive than at present, the exact distribution of the natural unmodified vegetation is unclear. Even as early as thel850s the area around 'The Blowhard' was described by Colenso as fern country with evidence of recent fires (Elder 1959).

Today the area is characterised by manuka-kanuka scrub, tussock and subalpine scrub, with small areas of beech forest, exotic forest and improved pasture. The distribution and condition of much of this vegetation has been described by Wallis (1966) and Cunningham (1971, 1974).

The manuka-kanuka scrub occurs wherever burning and grazing have been intensive, and is common south and east of the Kaweka Range and in a broad strip north and south of the Napier-Taihape Road as far west as the Ngamatea Plateau. Manuka scrub also occurs in the upper Taruarau and Ngaruroro catchments in association with tussock.

The tussock is of three types. In the upper Taruarau and Ngaruroro catchments red tussock is common on poorly drained slopes and high plateaux. It often occurs in association with *Dracophyllum* or manuka. It is also found in the Ngamatea Swamp and in No Man's Bog in the Northern Ruahine Range. Bristle tussock is found on formerly forested areas and areas highly modified by burning and grazing, mainly north of the Napier-Taihape Road and at a higher altitude than the manuka scrub. Snow tussock is found above the timberline on the Kaweka Range and above approximately 1200 m in the upper Taruarau and Ngaruroro catchments where it is often associated with subalpine scrub.

Beech forest is restricted to scattered 'islands', largely in association with the manuka-kanuka scrub, although occasionally in association with tussock. These 'islands' are remnants of a previously more widespread forest. They consist of red, silver or mountain beech, sometimes in combination, dependent mainly on altitude. Podocarps are very limited. Three remnants are the Blowhard Bush (podocarp-hardwood forest) and Boyds Bush and Paramahao Bush (both beech-podocarp forest).

Exotic forest has been established on many of the most severely eroded plateaux in the vicinity of 'The Blowhard', most of it *Pinus radiata.* At Makahu Saddle, on the eastern slopes of the Kaweka Range, and on the Black Birch Range revegetation trials (Figure 119) have been established (Cunningham 1981).

Improved pasture is of minor significance. Where the Napier-Taihape Road crosses the Ngamatea Plateau areas of red tussock have and are continuing to be converted to pasture.

On the eastern-most margin of the suite which adjoins the Hawke's Bay hill country, pasture has been extended onto some of the high ridges, usually at the expense of severe wind and sheet erosion. Areas of the Timahanga Basin, which lies between the Ngamatea and Blowhard Plateaux, have been converted from manuka-kanuka scrub to pasture. However, at an altitude of only 600 m this basin has a milder climate and is more sheltered than surrounding areas and is not subject to wind and sheet erosion. Therefore it has been included in LUC suite 11.

Land Use and Land Management

Past use has had a significant effect on vegetation and erosion and on present land management of LUC units within this suite. The following is a brief outline of the history of use within the area.

Forest was formerly far more widespread than at present, although tussock was the 'natural' vegetation in some areas such as the Ngamatea Plateau which Koch described as "tussock upland" in 1874. There were a number of Maori routes through the ranges and hunting parties were also known to use the area. It is probable therefore that sporadic fires affected the vegetation prior to European settlement (Elder 1959). The extent of fires resulting from volcanic eruptions is unclear. Early European travellers including Colenso (1884) mention fern and scrub, dead or dying beech forest and evidence of fires in the Blowhard-Southern Kaweka area.

The first record of European burning was in 1876 on the Blowhard Plateau. Fire was frequently used to clear fern and scrub for grazing and to promote growth of tussock. Most of the area has been affected by fire at least once, including the crest of the Kaweka Range. The burning of tussock was a regular practice in the upper Taruarau and Ngaruroro catchments. The use of fire is no longer common, although in 1983 a fire, started on Ohinewairua Station to the west of the Rangitikei River, spread out of control and burnt 1600 ha of scrub and tussock on Ngamatea Station, reaching the western slopes of Mt Meany.

Sheep were introduced into the upper Taruarau and Ngaruroro catchments in the early 1870s, on the Kaweka Range and Blowhard Plateau in 1873 and on the northern Ruahine Range about 1880. Initial numbers were high, but reduced considerably around 1900. Sheep were mustered off the Kaweka Range in 1905. Today grazing occurs on the Ngamatea Plateau, in the Timahanga Basin, at Kuripapango and on the eastern margin of the suite. Summer grazing still occurs in the upper Taruarau and Ngaruroro catchments and on the Otupae Range. Near Ngamatea Station root and green fodder crops are grown and cereal crops have been grown in the past. The main noxious animals in the area are deer, possums, hares and rabbits.

As a result of the widespread erosion centred on the Blowhard Pleateau the New Zealand Forest Service, commencing in 1964, has planted the area in introduced conifers. This area is now managed as a production forest. At Makahu Saddle the Forest Service and Ministry of Works and Development both have field stations, to carry out revegetation trials and hydrological studies respectively.

Most of the area of the suite east of the Ngaruroro River is in the Kaweka State Forest Park. A small area at the head of the Ngaruroro River is in the Kaimanawa State Forest Park and in the south a small area near the confluence of the Taruarau and Ngaruroro Rivers is in the

Ruahine State Forest Park. Apart from its general scenic value the area is used for a range of recreational activities, including tramping, hunting, fishing and canoeing.

All of the previously mentioned uses are conducted in an area where the conservation of soil and the regulation of water are the most important considerations. Past use has shown those practices that are incompatible with the physical properties of the land. Land use capability can be used to identify which land use practices are compatible with water and soil values.

Land Use Capability Units

The 11 LUC units in this suite have a generally low productive potential (Table 29). The range and intensity of use is also limited. Cropping is prevented by the climate and erosion potential, on slopes that are otherwise suitable for cultivation. Likewise the climate and erosion potential restrict the type of forestry and the grazing management.

The relationships between the LUC units and erosion potential, slope and altitude are shown in Figures 98 a,b.

LUC **unit IVe4 (1,840 ha)—**Figure 99

Undulating slopes between an altitude of 900 and 1000 m are mapped as IVe4. The unit is restricted to the Ngamatea Plateau surrounding the Ngamatea Swamp. Soils are Taruarau sandy loam and Ngamatea sandy loam and are developed on a trace of Ngauruhoe Ash overlying Taupo Pumice and Tongariro Ash. Because of the weakly developed soil structure, the loose, coarse nature of the tephras and the strong winds there is a severe potential for sheet, wind and rill erosion when cultivated. (Undulating slopes with a more favourable climate and less erodible soils are usually class II or class III.) The erosion potential, together with the climatic limitations of cold winter temperatures, frosts and winds limit the cropping potential. The unit is best suited to root and green fodder crops. Under pasture there is a negligible erosion risk but windbreaks are required if regular cultivation is practised. The vegetation north of Ngamatea Station Homestead is red tussock. Areas around the Napier-Taihape Road are presently being converted to improved pasture. Potential stock carrying capacity is 16 su/ha and site index for *P. radiata* is 15-22 m.

LUC **unit VIc2 (3,130 ha)—**Figure 99

VIc2 is also mapped on the Ngamatea Plateau, but where slopes are rolling to strongly rolling. The altitude range is 900-1000 m. In all other respects VIc2 is the same as IVe4. The slight increase in slope in this unit has made the risk of erosion by cultivation too great for it to be classified as IVe4. However, under a permanent tussock or pasture cover, sheet and wind erosion potentials are only slight. Under a grassland cover climate is now the major limitation to production and use.

Red tussock is the dominant vegetation with some scattered manuka. Again some improved pasture has been established near the Napier-Taihape Road. Potential stock carrying capacity is 13 su/ha and site index for *P. radiata* is 15-22 m.

LUC **unit IVw2 (1,380 ha)—**Figure 100

Ngamatea Swamp is a mixture of peat and pumice alluvium through which meanders a series of watercourses. The pumice is 5-15 m thick and overlies Miocene sand-stone/mudstone. The swamp is 880 m a.s.l. and is situated at the centre of the Ngamatea Plateau, receiving water from surrounding low hills. The vegetation consists of sedges and associated swamp vegetation in the wetter areas with some red tussock on higher drier sites. The outlet is through a steep narrow greywacke gorge into the Taruarau River.

The major limitation to use is one of wetness, both from the high water-table and the nature of the peat. Climate is also a limiting factor. Major drainage would be required to develop the swamp into pasture and cropping would still be a marginal use. Drainage would need to be slow and controlled to prevent damage to the peat and gullying of the underlying pumice.

Table 29: Production data and potential land use for LUC units on uplands and mountainlands with a mantle of highly erodible tephra

LUC Unit	Area (ha)	% Suite	Present Average Stock Carrying Capacity (su/ha)	Potential Stock Carrying Capacity (su/ha)	Site Index for *P. radiata* (m)	Potential Use
IVe4	3,130	6.2	1 1	16	15-22	Intensive grazing Occasional cropping Production forestry
IVw2	13,870	3.7	3	15	unsuitable	Grazing Occasional cropping
VIc2	6,560	20. 8	10	13	15-22	Grazing Production forestry
Vie 16	3,960	31. 6	5	9	18-24	Erosion control forestry Grazing
Vile 12	22,120 33,580	14. 3		5	15-22	Erosion control forestry Grazing
Vile 17	15,260			2	unsuitable	Erosion control forestry Extensive grazing
Vile 18	3,850	3.6		3	15-20	Erosion control forestry
VIIIe8	800	0.8	1	unsuitable	unsuitable	Protection forestry
VIIIe9	1.7		unsuitable	"	"	Protection grassland Protection forestry
VHIelO				"	"	Protection grassland
VHIell	1.3			"	"	Protection grassland
1,840	3.0					
1,380	13.0					

There is a potential for a stock carrying capacity of 15 su/ha after drainage, but because of wetness the unit would be unsuitable for forestry.

LUC unit Vie 16 (13,870 ha)—Figure 101

Vie 16 is mapped where slopes have increased from rolling, as in VIc2, to strongly rolling to moderately steep, with a consequent increase in erosion potential to severe. Vie 16 is also mapped where past land use has led to moderate to severe sheet and wind erosion on rolling slopes. The climate is still an important limitation to use but now erosion is identified as the major limitation. The altitude range is 700-1000 m and the unit occurs in two main areas. The first is on the Ngamatea Plateau from south of the Napier-Taihape Road and extending north into the headwaters of the Taruarau and Ngaruroro Rivers. Here the present erosion is slight sheet and wind. The second area is centred on the Blowhard and Mackintosh plateaux. Here slopes are slightly easier but there is an increase in present erosion. Sheet and wind erosion varies from slight to moderate and in several places to severe. This is largely the result of past burning and overgrazing opening up the vegetation and exposing the deposits of tephra.

The vegetation in the first area is mainly red tussock with scattered manuka and *Dracophyllum.* The area is extensively grazed. On the Blowhard and Mackintosh plateaux much of the area has been planted in exotic forest and is managed as a production forest. The remainder is in manuka-kanuka scrub. Potential stock carrying capacity is 9 su/ha and site index for *P. radiatah* 18-24 m. The wide range in site index reflects the altitudinal variation of the unit.

LUC unit VIIel2 (6,560 ha)

The rock types underlying the layers of tephra in Vie 16 are mainly sandstones, although north of Ngamatea Swamp the underlying rock is greywacke. Due to the depth of the tephra and the slope angle the underlying rocks have no significant effect on land use capability. However on steep to very steep slopes where the tephra is thin the underlying rock type becomes important. Hence in this situation 2 different LUC units were mapped, Vile 12 where the underlying rocks are Tertiary sandstones and limestones, and Vile 18 where the rock type is greywacke.

Vile 12 occurs in association with Vie 16 on steep slopes, especially near Kuripapango. Soils are yellow-brown pumice soils, typically those of the Te Pohue series. Sheet and wind are still the major erosion types, however because of an increase in slope angle and the influence of the sandstone, soil slip is also a characteristic erosion type. Soil slips remove the soil and tephra layers exposing bare sandstone faces which are very slow to revegetate. Much of the area is in manuka-kanuka scrub with some mixed indigenous scrub. There are also small areas with low producing pasture. Potential stock carrying capacity is down to 5 su/ha and site index for *P. radiata* down to 15-22 m. Erosion control forestry is the most suitable land use. Grazing requires the maintenance of a complete pasture cover and careful control of burning.

LUC unit VIIel7 (3,960 ha)—Figure 102

Undulating to strongly rolling exposed ridge tops between 1000 m a.s.l. and the timberline are mapped as Vllel7. The unit is similar to Vie 16 except that it occurs at a higher altitude which, because of the harsher climate, leads to an increase in the sheet and wind erosion potential to very severe. There is a corresponding decrease in potential stock carrying capacity to 2 su/ha. The unit is unsuitable for production forestry because of the altitude. Vegetation is red tussock, sub-alpine scrub and some highland beech forest.

Some areas of Vile 17, where the erosion potential is regarded as only slight, would be better classified as VIIc.

LUC unit Vllelg **(22,120** ha)—Figures 99, 102, 103

On steep to very steep slopes where greywacke is the underlying rock type Vllel8 is mapped. Kaweka and Otupae steepland soils are the main soil types. Here the tephra layers are thin to absent and the greywacke has important effects on land use. Production figures are very low with a potential carrying capacity of 3 su/ha and a site index for *P. radiata* of

15-20 m. Such low production potentials and a potential for very severe sheet and wind erosion and severe scree erosion make this unit very marginal for long-term production.

The unit occurs at altitudes below 1000 m throughout the Tutaekuri, Ngaruroro and Taruarau catchments where the main vegetation is manuka-kanuka scrub with pockets of beech forest. Tussock grassland is common in the upper Taruarau catchment.

Removal of the tephra by sheet and wind erosion leads to scree and occasional gully erosion. This ultimately leads to aggradation of the river system and increases the likelihood of flooding.

LUC unit VIIIe8 (33,580 ha)—Figures 99, 101, 102

VIIIe8 is mapped below an altitude of 1000 m where slopes are steeper and longer than those of VIIel8. The very steep slopes and very shallow soils lead to an extreme erosion potential. Erosion types are scree, sheet and wind, debris avalanche and gully. Sheet and wind erosion occur in the shallow tephra, exposing the underlying greywacke to scree and gully erosion. Present erosion is often severe with scree predominant over sheet and wind.

The unit occurs in gorges and on the lower slopes of the main ranges such as Kaweka, Otupae, Sparrowhawk and Burns Ranges. The vegetation is manuka-kanuka scrub and beech forest, much of the area, like VIIel8, having been burnt and overgrazed in the past.

The very steep slopes, shallow infertile soils, climate and particularly erosion potential all contribute to make this unit unsuitable for productive use. It is best used for catchment protection through protection forestry, fire prevention, noxious animal control and revegetation of eroded area.

LUC unit VIIIe9 (15,260 ha)—Figures 102, 103, 104, 105

Above an altitude of 1000 m on long very steep slopes VIIIe9 is mapped. The unit is similar to VIIIe8, but occurs at higher altitudes with a harsher climate. Here the erosion potential is still extreme but, because above 1000 m a.s.l. the tephra layer is more easily exposed, sheet and wind erosion predominate over scree erosion. Present erosion is more severe than in VIIIe8 and the higher altitude makes revegetation more difficult.

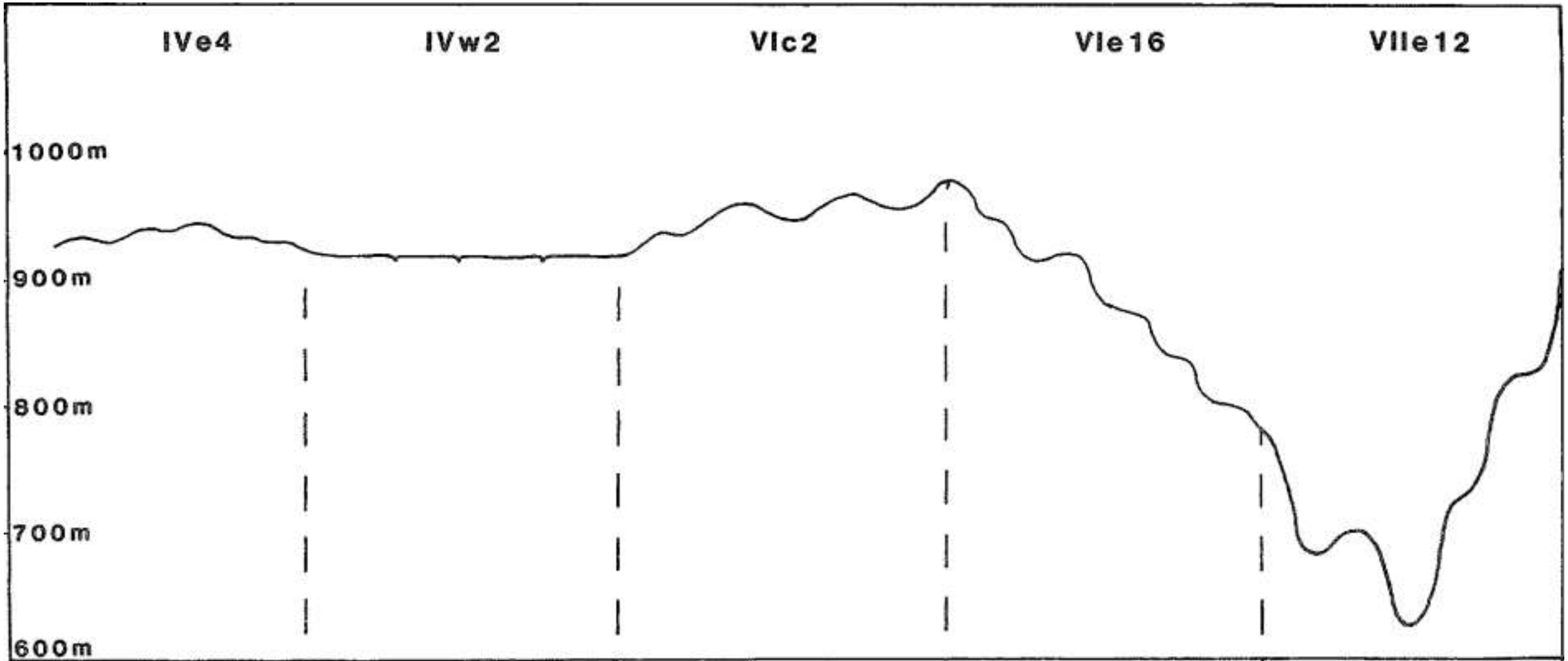
VIIIe9 is mapped on the upper slopes of the Kaweka, Otupae and Sparrowhawk Ranges and at the head of the Taruarau and Ngaruroro catchments.

Snow tussock and sub-alpine scrub predominate with small areas of highland beech forest, manuka and short tussock. As in the previous unit, VIIIe9 has a catchment protection function.

LUC units VlllelO (3,850 ha)—Figures 104, 106 and **Vlllell (800 ha)—**Figure 107

These two units occur above the timberline on undulating to rolling ridges and plateaux such as the crest of the Kaweka Range, Mt Meany and the slopes of the Tauwheketewhango Range. Here tephra is thicker than on the surrounding steeper slopes and the underlying greywacke is not usually exposed. Vegetation is sub-alpine scrub, snow tussock and sub-alpine herbs. These areas are very exposed; rainfalls in the vicinity of 3000 mm p.a. and very strong winds are common features.

The difference between the two units is based on present erosion severity. With VlllelO the present erosion is slight to moderate sheet and wind. With Vlllell present erosion is very severe to extreme. In both cases the potential for erosion is extreme if the indigenous vegetation is removed. However under the existing vegetation cover, and with only slight erosion, VlllelO would be better classified as VIIIc.



	IVe4	IVw2	VIc2	VIe16	VIIe12
Slope	B	A′	D, C	C+D, D+E	F, F+G
Altitude	900-1000m	900m	900-1000m	700-1000m	600-1000m
Erosion Potential	3Sh, 3R, 3W (when cultivated)	2G, 1W (when cultivated)	1Sh, 1W	3Sh, 3W, 2G	4Sh, 4W, 2sSl, 2G

Figure 98a: Relationship between LUC units on uplands and mountainlands with a mantle of highly erodible tephra.

1 600m

1400m

1200m

1 000m

800m

000m

400m

	VMe17	VIIe18	VilleS	VIIIe9	VIIIeIO	VIIIel 1
Slope	B, C, D	F+G			B, C	B, C
Altitude	1000-1 200m 400-1000 m	300-1000m	1000-1700m	1200-1600m	1300-1700m	
Erosion Potential	4Sh, 4W, 2G	4Sh, 4W, 3Sc, 2G, 2sSI	5Sc, 4Sh, 4W, ' 3G, 3daF	5Sh, 5W, 5Sc, I 3Q	5Sh, 5W, 4Sc	5Sh, 5W, 4Sc

Figure 98b: Relationship between LUC units on uplands and mountainlands with a mantle of

highly erodible tephra.

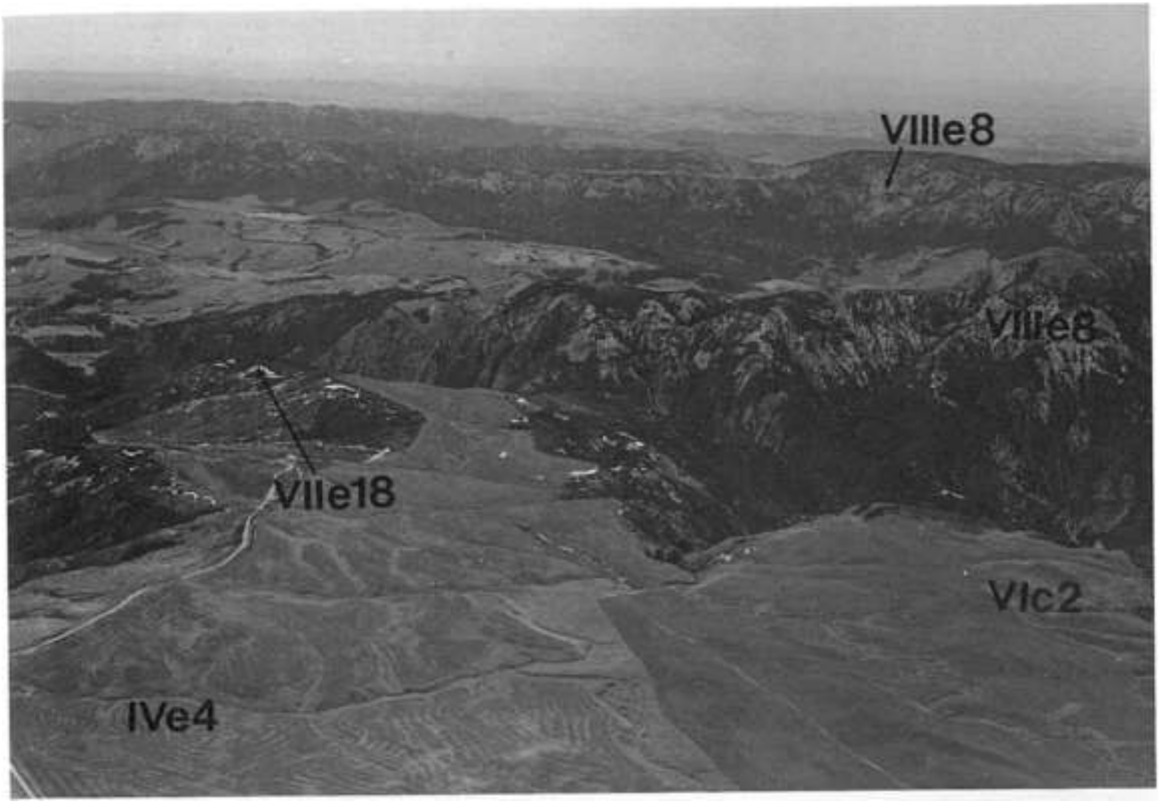


Figure **99:** IVe4. Ngamatea Plateau (foreground), on Napier-Taihape Road. IVe4 in left foreground. VIc2 in right foreground, Vile 18 in left centre, VIIIe8 in right centre and background. N123/640450, looking east.

Figure 100: IVw2. Ngamatea Swamp, north of Napier-Taihape Road. N123/605530, looking north-east.

Figure 101: VIe16. Blowhard Plateau, north of Napier-Taihape Road. VIIIe8 in background. N123/830555, looking east.

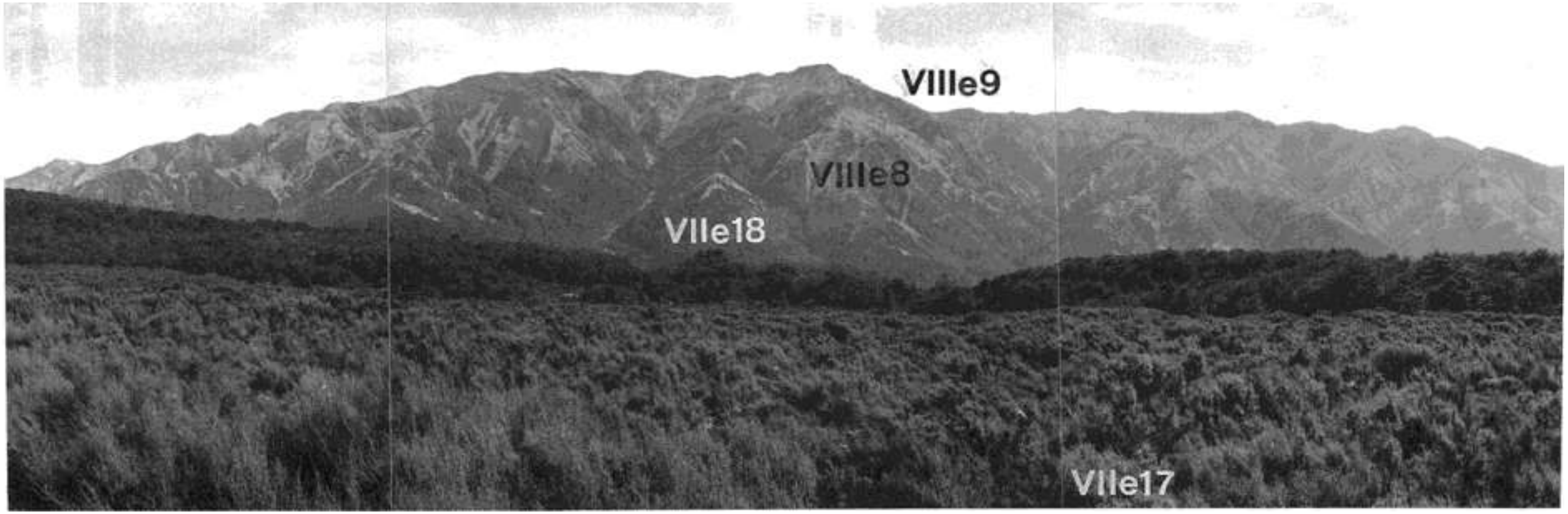


Figure 102: VIIel7 in foreground. Kaweka Range from Littles Clearing. N123/840660, looking west. Vile 18 on lower slopes of range, VIIIe8 on mid-slopes, VIIIe9 on upper slopes^

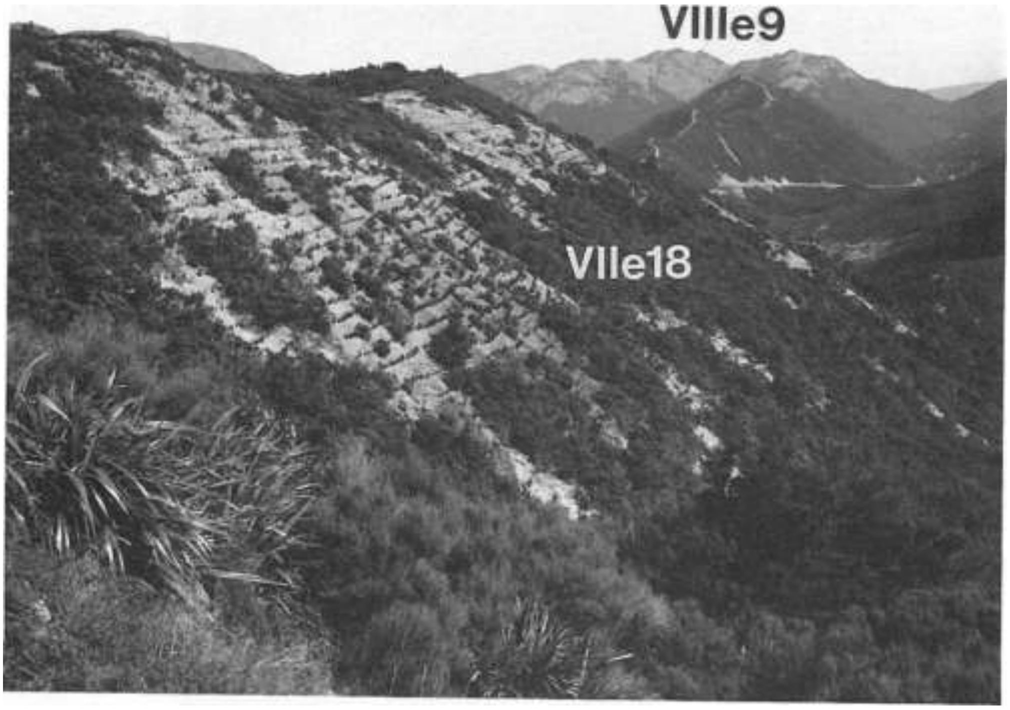


Figure 103: VIIel8. From road to Black Birch Range. Don Juan in distance (VIIIe9) N124/908646, looking south.

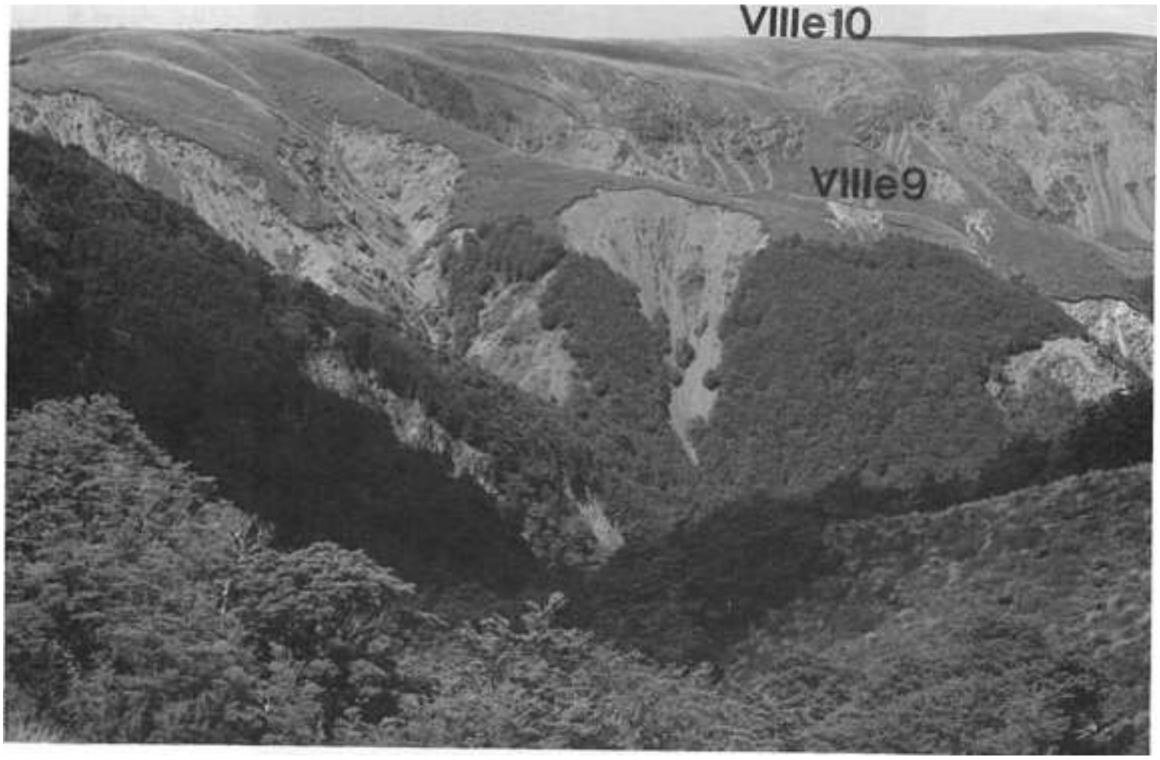


Figure 104: VIIIe9. Northern Ruahine Range, from No Man's Bog. N133/715275, looking south-east. VlllelO on skyline. Photo: P M Blaschke

Figure 105: VIIIe9. Crest of Kaweka Range. N123/839687, looking north-east. Photo: N A Trustrum

Figure 106: VHIelO. No Man's Bog, Northern Ruahine Range. N133/705286, looking north-west. Photo: P M Blaschke

Figure 107: VIIIe11. Crest of Kaweka Range. N123/826646, looking north. Photo: N A Trustrum

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Areas of LUC Units Mapped in the Northern Hawke's Bay Region.

This appendix lists all the LUC units in the Region in the order in which they appear in the regional LUC extended legend (Page 1976a).

LUC Unit	Unit Total	Subclass Total	Class Total	% of Region
Icl	4,410	4,410		
Iwl	6,700	6,700		
			11,110	1.0
Ilel	3,430	3,430		
IIwl	10,740	10,740		
			14,170	1.2
Illel	2,640			
IIIe2	1,100			
IIIe3	4,750	8,490		
IIIsl	2,560			
IIIs2	5,610			
IIIs3	14,390			
IIIs4	3,150			
IIIs5	600	26,310		
IIIwl	17,900			
IIIw2	3,620	21,520		
IVcl	1,740	1,740	56,320	4.9
IVel	7,470			
IVe2	33,180			
IVe3	1,170			
IVe4	1,840			
IVe5	4,980	48,640		
IVsl	250			
IVs2	3,840	4,090		
IVwl	1,150			
IVw2	1,380	2,530		
			57,000	5.0
Vcl	3,800	3,800		
			3,800	0.3
VIel	80			
VIc2	3,130			
VIc3	3,320	6,530		
VIel	97,240			
VIe2	13,090			
VIe3	31,140			
VIe4	10,680			
VIe5	37,330			
VIe6	111,150			
VIe7	35,250			
VIe8	9,190			
VIe9	1,600			
VIelO	9,380			
VIell	55,810			
Vie 12	10,940			
VIel3	2,250			
VIel4	17,130			
VIelS	10,120			
VIel6	13,870	466,170		
VIsl	150			
VIs2	770			
VIs3	610	1,530		
VIwl	660	660		
			474,890	41.2
Vllel	21,460			
VIIe2	35,650			
VIIe3	16,290			
VIIe4	15,180			
VIIe5	19,040			
VIIe6	14,070			
VIIe7	82,200			
VIIe8	2,030			
VIIe9	31,840			

APPENDIX 1

LUC Unit	Unit Total	Subclass Total	Class Total	% of Region
VllelO	1,830			
Vile 11	5,790			
Vile 12	6,560			
VIIel3	1,050			
VIIeH	49,260			
Vile 15	1,140			
Vile 16	1,870			
VIIel7	3,960			
VIIe-18	22,120			
Vile 19	5,250	336,590		
VIIsl	640	640		
VIIwl	300	300	337,530	29.3
VHIel	450			
VIIIe2	11,730			
VIIIe3	1,300			
VIIIe4	6,270			
VIIIe5	95,400			
VIIIe6	3,230			
VIIIe7	1,550			
VIIIe8	33,580			
VIIIe9	15,260			
VlllelO	3,850			
Vlllell	800	173,420		

Reference:

Page, M.J. 1976a: New Zealand Land Resource Inventory Northern Hawke's Bay Region: land use capability extended legend. National Water and Soil Conservation Organisation, Wellington, New Zealand.

APPENDIX 2

Correlation of LUC Units Mapped in the Northern Hawke's Bay Region with LUC Units in Adjacent Regions (Page 1985).

Region 7 Northern Hawke's Bay	Region 4 Bay of Plenty—Volcanic Plateau	Region 5 Eastern Bay of Plenty	Region 6 Gisborne—East Coast	Region 8 Southern Hawke's Bay-Wairarapa	Region 10 Taranaki-Manawatu
Icl				Icl (north of Takapau Plains)	
Iwl				Iwl (north of Waipukurau)	
Ilel					
II wl			II wl	IIwl (north of Waipukurau)	
Illel				IIIe2	
IIIe2					
IIIe3					
IIIsl				IIIsl	
IIIs2				IIIs2	IIIs2
IIIs3					
IIIs4					
IIIs5*	IVs2	IVsl			
IIIwl (plains)				IIIw2 (north of Waipukurau)	
IIIwl (narrow valleys)			IIIwl	IIIwl (north of Waipukurau)	
IIIw2					
IVcl*					IVc4
IVel				IVe2	
IVe2			IVe3		
IVe3	IVel 7				
IVe4*					IVel 2
IVe5	IVel 8				IVel4
IVsl*	IVs2	IVsl			
IVs2	IVs5				IVs3
IVwl	IVwl	IVwl	IVwl	IVwl	IVw2
IVw2					IVw4
Vcl				Vcl	
VIcl					
VIc2					VIc3 (south of Waiouru)
VIc3					
VIel			VIe3		
VIe2*					VIe2
VIe3 (>1200 mm pa)			VIe6 (>1200 mm pa)	VIe7	VIe3
VIe3 (<1200 mm pa)			VIe6 (<1200 mm pa)	VIe8	VIe4
VIe4			VIe7		

APPENDIX 2

VIe5		VIe5	
VIe6	VIe8		
VIe7			
VIe8			
VIe9	VIell		VIell*
Vie 10		Vie 10	
(bentonitic		(bentonitic	
>1200 mm pa)		>1200 mm pa)	

Region 7 Northern Hawke's Bay	Region 4 Bay of Plenty-Volcanic Plateau	Region 5 Eastern Bay of Plenty	Region 6 Gisborne—East Coast	Region 8 Southern Hawke's Bay-Wairarapa	Region 10 Taranaki-Manawatu
VIelO (non-bentonitic >1200 mm pa)			VIe5	VIelO (non-bentonitic >1200 mm pa)	VIe20
VIell (E, E+D slopes)	Vie 18	VIe4			
VIell (D, D+E slopes)		VIe3			
Vie 12	VIe21	VIe5	Vie 13 (with tephra)		
VIel 3				VIel4	VIe24
VIel4			VIelO		
VIelS	VIe22				
Vie 16					VIe27
VIsl*				VIs4 (non-coastal)	VIs7 some IIIwl
VIs2*	VIwl (saline areas)				VIwl (saline areas)
VIs3				VIs4 (non-coastal)	VIs7 some IIIwl
VIwl	VIwl			VIwl	
Vllel (>1200 mm pa)			Vllel (>1200 mm pa)	Vllel (>1200 mm pa)	Vllel
Vllel (<1200 mm pa)			Vllel (<1200 mm pa)	Vllel (<1200 mm pa)	VIIe2
VIIe2		(with tephra) Vllel (inland areas)	VIIe2 (with tephra)	VIIe2	VIIe7
VIIe8*			VIIe9		
VIIe9			VIIe9		
VllelO			VIIeH		
Vllel 1			Vile 16		
Vile 12				VIIe21	
Vllel 3		VIIe3	Vlle21	Vllel 5	
VIIel4	Vllel 1			Vllel 1 (Hauhun-garoa area)	
Vile 15			VIIel8		
Vllel 6*	Vile 12				
Vile 17 (erosion potential severe or greater)				Vile 19 VIIe24 (erosion potential severe or greater)	
Vile 17 (erosion potential slight to moderate)	Vllel		Vile 14		
			Vile 13	VIIcl	

Region 7 Northern Hawke's Bay	Region 4 Bay of Plenty—Volcanic Plateau	Region 5 Eastern Bay of Plenty	Region 6 Gisborne—East Coast	Region 8 Southern Hawke's Bay-Wairarapa	Region 10 Taranaki-Manawatu
					VIIe24 (erosion potential slight to moderate)
Vile 18				VllelO (Wakarara Range)	VIIe22
Vile 19	Vile 14				
VIIsl			Vile 19*	VIIsl (non-coastal)	
VIIwl*	VIIIwZ				VIIIwl
VHIel	VHIel		VHIel	VIIIe4	Vlllel
VIIIe2			VIIIe2 (gorges and bluffs)	Vlllel	VIIIe3 (gorges and bluffs)
VIIIe3			VIIIe2 (coastal cliffs)	VIIIe2	VIIIe3 (coastal cliffs)
VIIIe4	VIIIe2				VIIIe2*
VIIIe5	VIIIe3	VHIel	VIIIe3	VIIIe5	VIIIe4
VIIIe6	VIIIe4	VIIIe2	VIIIe4	VIIIe6	VIIIe7
VIIIe7					VIIIe6
VIIIe8				VIIIe7	VIIIe5
VIIIe9	VIIIe7	VIIIe4	VIIIe5	VIIIe9	VIIIe9
VlllelO	VIIIcl			VIIIcl	VIIIcl

*approximate or moderate correlation only.

Reference:

Page, MJ. 1985: Correlation of North Island regional land use capability units from the New Zealand land resource inventory. *Water and Soil Miscellaneous Publication No.* 75. 108 p.

APPENDIX 3

Correlation of LUC Units Mapped in the Northern Hawke's Bay Region with Landform Suites (Black and Cairns 1983).

Landform Suites	LUC Units	LUC Suites
Alluvial terrace	Icl,Iwl,IIwl,IIIwl,IIIw2	Alluvial plains and terraces
(Raupunga)	IIIe2,VIcl	Raised marine terraces
	IIIe3,IIIs3	Taupo airfall tephra
	VIs3	Gravel terraces
Pumice upland	IVe2,VIel,VIe6,VIel l,VIIel4	Taupo airfall tephra
(Kotemaori)	VIIe8	Sandstone hill country
Coastal steepland	VIe2	Loess
(Waihua)	VIe3, Vllel	Jointed mudstone hill country
	VIe4,VIIe2	Banded mudstone hill country
	VIe7,VIIe4	Siltstone hill country
	VIe8,VIel4,VIIe5	Sandstone hill country
	Vie 12	Greywacke mountain and hill country
Steepland	VIIe9,VIIIe2,VIIIe3	Sandstone hill country
(Mohaka)	Vllel l,VIIIe2,VIIIe3	Banded mudstone hill country
	VIIIe5,VIIIe6	Greywacke mountain and hill country
	VIIIe5,VIIIe6,VIIIe7	Taupo airfall tephra
Earthflow	VIsl	Sandstone hill country
(Hineroa)	VIelO,VIIe6,VIIelO	Unstable mudstone terrain
Duneland (Opoutama)	Vie 13,VIIe 13, Vlllel	Sand dunes
Coastal alluvium	IVsl	Sand dunes
(Whakaki)	IVwl,VIwl,VIIwl	Alluvial plains and terraces

Reference:

Black, R.D.; Cairns, I.H. 1983: Wairoa District Land Resource Study. Hawke's Bay Catchment Board and Regional Water Board Report (unpublished).

APPENDIX 4

Stock Carrying Capacity Data for LUC Units in the Northern Hawke's Bay Region.

LUC Unit	Present Average (su/ha)	Top Farmer (su/ha)	Attainable Physical Potential (su/ha)
fc\	~~ 20	is	
Iwl	17		32
	25		32
Ilel	15		20
	15		30
IIwl	18		22
	25		20
Illel	16		20
	19		20
IIIe2	10		23
	17		15
IIIe3	10		20
	17		12
IIIsl	15		26
	16		17
IIIs2	14		10
	16		22
IIIs3	10		20
	12		11
IIIs4	14		16
	14		15
IIIs5	5 7		10
IIIwl	12		15
	17		15
IIIw2	11		15
	15		20
IVel	_	_	10
IVel	16		13
	19		12
IVe2	10		20
	17		17
IVe3	9 o		16
IVe4	11		14
	14		17
IVe5	11		17
	H		17
IVsl	5 7		11
IVs2	11	10 13	
	15		
IVwl	10	12	
IVw2 Vcl	3 3		
	12	16	
VIcl	5 5		
VIc2	10	n	
VIc3	6 9		
VIel	10	17	
VIe3	10	12	
VIe4	9	i f	
VIe5	12	17	
VIe6	9	J 5	
VIe7	10	12	
VIe8	7	o	
VIe9	9		
VIell	7	9 A J	11
VIel2 VIe 14	7 4	7 10 4 q 12	
VIel5	10		
	i o y		12
VIel6	5	5	9
VIsl	5	I	10
VIs2	7	12 15	
	, 2		
VIs3	5	5 J o	
VIwl	5	I \I	
VIIe2	7 10		
X"e3	7 J"		

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			1 5 1 2
VIIe4	7		[ϱ \\
VIIe5	5		9 1
VIIe6	5		9
VIIe7	2		? 7
VHeS	5		6 9
VIIe9	5		6 *I*
VllelO	9		i n
Vllell	5		5
VIIel2	_		_
VIIel3	3		3
VIIel4	3		3
VHel5	5		5 *1*
VIIel6	10		10 12
X5ei	7	ii 12	

LUC Unit	Present Average (su/ha)	Top Farmer (su/ha)	Attainable Physical Potential (su/ha)
VIIel7	1	2	2
VIIel8	1	2	3
VIIel9	8	8	11
VIIsl	5	5	7
VIIwl	—	—	5

APPENDIX 5

Site Index Data for LUC Units in the Northern Hawke's Bay Region.

LUC Unit	Site Index *(Pinus radiata* in metres)	LUC Unit	Site Index *(Pinus radiata* in metres)
Icl	33 +	VIe7	29-32
Iwl	33 +	VIe8	30-32
Ilel	35 +	VIe9	30-34
IIwl	33 +	VIelO	30-33
Illel	27-32	VIell	22-29
IIIe2	33-35	Vie 12	23-30
IIIe3	32-34	Vie 13	25-28
IIIsl	27-32	Vie 14	24-32
IIIs2	25-30	VIel5	25-30
IIIs3	33-35	Vie 16	18-24 (some areas unsuitable)
IIIs4	Unsuitable	VIsl	30-32
IIIs5	25-30	VIs2	Unsuitable
IIIwl	30-32	VIs3	23-28
IIIw2	Unsuitable	VIwl	Unsuitable
IVcl	23-28	Vllel	28-32
IVel	27-32	VIIe2	28-30
IVe2	28-33 (23-28 in areas above 600 m a.s.l.)	VIIe3	25-30
		VIIe4	27-31
IVe3	25-30	VIIe5	25-30
IVe4	15-22	VIIe6	28-32
IVe5	25-30	VIIe7	20-29
IVsl	25-30	VIIe8	25-32
IVs2	25-30	VIIe9	24-29
IVwl	Unsuitable	VllelO	27-29
IVw2	Unsuitable	Vile 11	27-29
Vcl	27-31	VIIel2	15-22
VIel	20-24	Vllel 3	25-28
VIc2	15-22	VIIel4	20-29
VIc3	Unsuitable	VIIel5	26-29
VIel	30-33	VIIel6	Unsuitable
VIe2	27-31	VIIel7	Unsuitable
[illegible]	[illegible]	[illegible]	[illegible]

APPENDIX 6

Authors and Dates of Field Work of the New Zealand Land Resource Inventory Worksheets in the Northern Hawke's Bay Region.

Worksheet No.	Worksheet Name	Author	Date of fieldwork
pt N95	Te Whaiti	M J Page	Feb 1975
pt N96	Maungapohatu	M J Page	Jan 1975
N97	Ngatapa	M J Page	May 1974
pt N98	Gisborne	M J Page	Oct 1975
pt N103	Rangitaiki	M J Page	Feb 1975
pt N104	Maungataniwha	M J Page	Mar 1975
N105	Waikaremoana	M J Page	Jan 1975
N106	Tiniroto	M J Page	Aug 1974
N107	Wharerata	M J Page	May 1974
pt N113	Kaweka	M J Page	Feb 1976
N114	Tutira	M J Page	Mar 1975
N115	Mohaka	M J Page	Jan 1975
N116	Wairoa	M J Page	Jun 1974
N117,126 and 127	Mahia	M J Page	Sep 1974
pt N123	Ngamatea	M J Page	Jan-Feb 1976
N124	Esk	M J Page	Oct 1975
N125	Tangoio	M J Page	Apr 1975
pt N133	Wakarara	P R Stephens	Feb-Apr 1976
		K E Noble	Feb 1977
pt N134	Napier and Hastings	K E Noble	Mar 1976

When quoting information from individual worksheets, the correct reference is: e.g. Page, M.J. 1975: N105 Waikaremoana, NZ Land Resource Inventory Worksheet, NWASCO, Wellington. Part sheets are referenced by the principal authors for that part of the worksheet.

Author and date of field work apply only to that part of the worksheet within the Northern Hawke's Bay Region.

APPENDIX 7

Aerial Photographs used in the Compilation of the New Zealand Land Resource Inventory Worksheets in the Northern Hawke's Bay Region.

Worksheet No.	Worksheet Name	Date	Photographs Scale		Survey No*
pt N95	Te Whaiti	1952	1	18909	542
pt N96	Maungapohatu	1970	1	18750	3122
		1965	1	26181	1774
N97	Ngatapa	1965	1	26181	1774
pt N98	Gisborne	1972	1	24727	3560
pt N103	Rangitaiki	1965	1	66666	1698
pt N104	Maungataniwha	1969	1	27636	3203
		1971	1	80000	2301
N105	Waikaremoana	1964	1	26181	1703
N106	Tiniroto	1964	1	26181	1703
N107	Wharerata	1964	1	26181	1703
pt N113	Kaweka	1952	1	24727	801
N114	Tutira	1964	1	26909	1704
		1962	1	17454	1455
N115	Mohaka	1970	1	25454	3299
N116	Wairoa	1970	1	25454	3299
N117,126 and 127	Mahia	1973	1	24500	2637
pt N123	Ngamatea	1952	1	24727	801
N124	Esk	1970	1	25454	3299
N125	Tangoio	1970	1	25454	3299
pt N133	Wakarara	1972	1	27636	3590

*New Zealand Aerial Mapping Ltd, Hastings

APPENDIX 8

Geological Maps used in the Northern Hawke's Bay Region.

Grindley, G.W. 1960: Sheet 8 Taupo (1st Ed) 'Geological Map of New Zealand 1:250,000'. Department of Scientific and Industrial Research, Wellington, New Zealand.

Kingma, J.T. 1962: Sheet 11 Dannevirke (1st Ed) 'Geological Map of New Zealand 1:250,000'. Department of Scientific and Industrial Research, Wellington, New Zealand.

Kingma, J.T. 1964: Sheet 9 Gisborne (1st Ed). 'Geological Map of New Zealand 1:250,000'. Department of Scientific and Industrial Research, Wellington, New Zealand.

Kingma, J.T. 1970: Sheets N134 Napier and Hastings, N135 Kidnappers (1st Ed) 'Geological Map of New Zealand 1:63,360'. Department of Scientific and Industrial Research, Wellington, New Zealand.

O'Byrne, T.N. 1967: A Correlation of Rock Types with Soils, Topography and Erosion in the Gisborne-East Cape Region. *New Zealand Journal of Geology and Geophysics 10(1):* 217-31.

APPENDIX 9

Soil Surveys used in the Northern Hawke's Bay Region.

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Rijkse,W.C.inpreparation: Soil map of Taupo County. New Zealand Soil Bureau, Rotorua.

APPENDIX 10

Vegetation Maps used in the Northern Hawke's Bay Region.

New Zealand Forest Service, 1970: FSMS6 Sheet No 7 Urewera (1st Ed). "Forest Class Map 1:250,000". Forest Research Institute, New Zealand Forest Service.

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APPENDIX 11

NZLRI Rock Type Classification*

Volcanic Lithologies			Sedimentary Lithologies		
Ng	—	Ngauruhoe ash	Pt	—	Peat
Ta	—	Tarawera ash and lapilli	Wb	—	Sands—windblown
Rm	—	Rotomahana ash	Lo	—	Loess
Kt	—	Kaharoa and Taupo ashes	Al	—	Undifferentiated floodplain alluvium
Mo	—	Ashes older than Taupo ash	Gr	—	Gravels
Lp	—	Lapilli	Us	—	Unconsolidated silts, ashes, sands, tuffs and breccias
Tp	—	Taupo and Kaharoa breccia and volcanic alluvium	Mm	—	Mudstone or fine siltstone—massive
Ft	—	Breccias older than Taupo breccia	Mb	—	Mudstone or siltstone—banded
La	—	Lahar deposits	Mj	—	Mudstone or siltstone—jointed
Vo	—	Welded volcanic rocks	Me	—	Mudstone—bentonitic
Gn	—	Crystalline intrusive rocks	Sm	—	Sandstone or siltstone—massive
			Sb	—	Sandstone—banded
			Ar	—	'Argillite'
			Ac	—	'Argillite'—crushed
			Li	—	Limestone
			Gw	—	'Greywacke'

Note: " or ' — deep weathering e.g. Gw°
+ — two or more rock types present, the first dominant e.g. Gw + Ar
/ — stratigraphic sequence, surface rock type first e.g. Kt/Mo/Vo
() — significant in patches e.g. (Lo)/Gr.

* As at 1976

APPENDIX 12

NZLRI Slope Classification

Slope Groups	Slope Angle in Degrees	Relief
A	0-3	Flat to gently undulating
B	4-7	Undulating
C	8-15	Rolling
D	16-20	Strongly rolling
E	21-25	Moderately steep
F	26-35	Steep
G	>35	Very steep

Additional Symbols:

D/E — Average slope between two slope groups
A + B — Complex slopes, first slope group is dominant
A' — Dissected slopes

NZLRI Erosion Type and Severity Classifications

Erosion Type	**Erosion Severity**
Surface Erosion Sh — sheet W — wind Sc — scree	recorded on an areal basis
Mass Movement Erosion sSl — soil slip eSl — earth slip Su — slump daF — debris avalanche eF — earthflow mF — mudflow	recorded on a seriousness basis (a combination of rate and depth of movement, frequency of erosion events, feasibility and cost of control, economic effect)
Fluvial Erosion R — rill G — gully T — tunnel gully Sb — streambank D — deposition	

		percentage bare ground (surface erosion only)
0	— negligible	< 1
1	— slight	1 - 10
2	— moderate	11 - 20
3	— severe	21-40
4	— very severe	41-60
5	— extreme	>60

NZLRI Vegetation Classification*

Grassland

P	— Unspecified grassland
P I	— High producing pasture
P2	— Low producing or native grassland
P3	— Short tussock associations
P4	— Snow tussock associations
P5	— Red tussock associations
P6	— Sand dune associations

Cropland

L	— Unspecified crops
Ll	— Cereals
L2	— Orchards and vineyards
L3	— Root and green fodder crops
L4	— Horticulture

Scrubland

M	— Unspecified scrub associations
Ml	— Manuka, kanuka
M2	— Tauhinu *(Cassinia)*
M3	— *Dracophyllum*
M4	— Fern
M5	— Sub-alpine scrub associations
M6	— Mixed native scrub associations
M7	— Broom
M8	— Gorse
M9	— Blackberry
M10	— Sweet briar
M i l	— Matagouri
M12	— Mangroves

Forest

N	— Unspecified forest associations
N l	— Coastal forest
N2	— Kauri
N3a	— Podocarp—hardwood (lowland)
N3b	— Podocarp—hardwood (mid-altitude)
N4a	— Nothofagus (lowland)
N4b	— Nothofagus (highland)
N5	— Hardwood
N6	— Exotic forest
N7	— Podocarps
N8	— Conservation trees

Weeds, Herbs etc

H	— Unspecified herbaceous plant associations

NOTE: upper case indicates vegetation comprises >40% of map unit, and lower case <40%.
* As at 1976

APPENDIX IS

Soil Sets and Series recorded in the Northern Hawke's Bay Region.

The following is a list of all soil sets and soil series recorded on NZLRI worksheets in the Northern Hawke's Bay Region. It also shows that soil survey or surveys in which each soil was recorded. Soil names from the General Survey refer to soil sets, and soil names from all other surveys refer to soil series.

Key to soil survey numbers:

1. General Survey
2. Mid Hawke's Bay Survey
3. Heretaunga Plains Survey
4. Gisborne Plains Survey
5. Rangitikei County Survey
6. Wairoa County Survey
7. Taupo County Survey.

Soil set/ Series name	Soil survey number						
	1	2	3	4	5	6	7
Ahuriri	X						
Argyll*					X		
Aromoana		X					
Ashcott						X	
Atua						X	
Awamate						X	
Crownthorpe		X					
Esk		X					
Farndon			X				
Gisborne	X	X				X	
Hangaroa	X					X	
Hastings		X	X				
Irirangi					X		
Kaingaroa							X
Kaiti				X		X	
Kaweka	X	X			X		
Kidnappers		X					
Kopuawhara						X	
Mahia						X	
Mahoenui	X					X	
Makahu							X
Makaraka				X			
Makauri				X		X	
Mamaku	X					X	
Manawatu	X						
Mangamahu						X	
Mangatea						X	
Matapiro		X					
Matawai	X					X	
Matawhero				X			
Meeanee			X				
Moawhango					X		
Mohaka	X					X	
Mokamoka		X					
Mokau	X						
Moumahaki	X					X	
Muriwai				X			
Ngamatea					X		
Ngaroma	X	X					

APPENDIX IS

Okawa							
Opoutama				X		X	
Oruanui							X
Otamatea					X		X
Otamauri	X						
Otupae					X		
Pahiatua						X	
Pakarae	X					X	
Pakowhai		X	X				
Pongakawa	X					X	

Soil set/ Series name 6 7	Soil survey number 1 2 3 4 5
Poporangi	X ~
Poronui **X**	
Pouawa X	
Poukawa X	
Puaroa X	
Pukerimu X	
Puketitiri X	
Raukawa X	
Rawea X	
Ruahine[1]	X X
Ruakituri X	
Taihape	X X
Takapau X	
Tangoio X	
Taruarau X	
Tauhara X	
Taupo	X X
Te Hapara X	
Te Pohue X	
Tihoi X	
Tiniroto X	
Titapu X	
Titiokura X	
Tuai X	
Tukituki	X X
Turakina X	
Tutira	X X X
Twyford	X X
Urewera	X X
Waiaruhe X	
Waihirere	X X
Waihua	X X X
Waikaremoana X	
Waikoau X	
Waikonini X	
Waipaoa	X X
Waipukurau X	
Waipunga X	
Waitaha	X X
Waiwhare X	
Whakaki x	
Whangaehu	X X
Whangamomona	X X
Wharerata	X X

1Argyll and Ruahine soils were recorded on the interim soil map of Rangitikei County and were used on the worksheets. On the published soil map they have been renamed Tarata and Rimutaka respectively.

APPENDIX 16

Erosion Associations in the Northern Hawke's Bay Region.

Each LUC unit has a characteristic erosion pattern. The erosion type or combination of erosion types that occur do so under certain conditions and in a particular sequence. These patterns of erosion have been categorised into erosion associations which have been mapped at 1:250,000 in the "Erosion Map of New Zealand" series. Twenty one erosion associations have been identified throughout New Zealand and of these fourteen occur within the Northern Hawke's Bay Region. The following table lists these fourteen associations, describes their key physical factors and gives the main locations of each association within the Region.

Erosion Association	Key Physical Factors	Main Areas in Region
B Frost heave, sheet and gully erosion. Minor debris ava— lanche, slip and scree creep erosion. *VIIIe9*	creep erosion. *Vllel 8 VIIIe8 VIIIe9* Steep to very steep mountain ranges. Sub-alpine grasslands and herbfields on hard rocks, e.g. gneiss, diorite, granite, schist and greywacke.	Tops of Kaweka, Kaimanawa and Ruahine Ranges.
C Slip and debris avalanche erosion. Minor gully erosion. *Vllel VllleS VIIIe6*	Steep to very steep, forested montane slopes. Greywacke, schist and other hard rocks.	Urewera, Ahimanawa and northern Kaweka Ranges.
D Frost heave, wind and sheet erosion. Gully, debris ava— lanche and scree	Steep to very steep tussock covered mon-tane slopes.	Kaimanawa, Kaweka and northern Ruahine Ranges.
Frost heave, wind and sheet erosion leading to an erosion pavement. *Vllel 7 Vlllel 0 Vlllel 1*	Flat to rolling slopes, either inter-montane basins or uplands.	Plateaux and ridges in upper Taruarau and Ngaruroro catchments.
Sheet and scree creep erosion. Minor slip erosion. *VIel 2*	Steep hill country. Greywacke, schist and other indurated rocks.	Foothills of ranges near Te Haroto.
H Slip and sheet erosion. *Vcl VIel VIe2 VIe4 VIe5 VIe6 VIe7 VIe8 VIell VIel4 VIsl VIM VIIe3 VIIe4 VlleS VIleB VIIe9 Vllel 1 Vllel 2 Vllel 4 VII'lei VIIIe3 VllleS Vllle6 Vlllel Vlllsl*	Steep hill country. Indurated siltstones and conglomerates.	Extensive throughout hill country between Napier and Gisborne. Lake Waikaremoana.
J Slip and shallow earthflow erosion. Minor slump and gully erosion. *VIe3 Vllel*	Moderately steep to steep hill country. Indurated siltstones and mudstones.	Hill country in inland Wairoa and Gisborne districts.
Deep earthflow and gully erosion. Minor slip erosion. *VIe9 VIelO VIIe6 VllelO* Strongly rolling to moderately steep hill country. Crushed argillites and loose jointed mudstones,	frequently bentonitic. Hill country in inland Wairoa and Gisborne districts.	

Erosion Association	Key Physical Factors	Main Areas in Region
M Large, deep-seated gully erosion, slip erosion and minor flow erosion. *VIMS*	Moderately steep to steep hill country. Crushed argillites and mudstones.	Hill country at confluence of Waipunga and Mohaka Rivers, and at confluence of Hautapu and Te Hoe Rivers.
Sheet, wind and terracette forma— tion. Gully erosion. *VMS VM6 VIcl VIM 7 VIM 9*	Strongly rolling to steep hill country. Rhyolitic and recent ashes.	Kaweka and Ahimanawa Ranges.
R Wind and sheet erosion. Gully and tunnel gully erosion. *IVe3 IVe4 IVeS IVsl IVel VIM 6 VIIU4*	Flat to undulating plains and terraces. Rhyolitic and recent ashes. Hill country flanking the Kaimanawa,	Terraces and downland scattered throughout the mountain ranges.
Sheet and rill erosion. Minor gully erosion and wind erosion. *IIM IUe3 IVel IVel VIcl VIc3*	Undulating to strongly rolling downlands.	
T Wind erosion and deposition. *IM Illel IIIsl IIIsl IIIs3 IIIsS IVsl VM3 VIM3 VIIsl VIIM*	Plains, terrace lands and sand dunes.	Coastal areas between Wairoa and Mahia Peninsula. Terraces between Napier and Wairoa.
U Negligible erosion to slight streambank erosion. Inter— mittent flooding and deposition. *Iwl Icl IIwl IIIwl IIIwl IIIs4 IVwl IVwl VIwl VIsl VIs3 VIIwl VIIsl*	Lower terraces, flood— plains and wetlands. Alluvial sediments with generally high water tables. Downland scattered throughout the hill country.	Gisborne, Wairoa and Heretaunga Plains, and numerous river valleys.

APPENDIX 17

Ecological Regions and Districts.

The following Ecological Regions and Districts occur within the Northern Hawke's Bay Region.

pt	Turanga District	East Cape Region
pt	Tiniroto District	Wairoa Region
	Waihua District	Wairoa Region
	Mahia District	Wairoa Region
	Waikaremoana District	Urewera Region
pt	Ikawhenua District	Urewera Region
pt	Kaingaroa District	Eastern Volcanic Plateau Region
pt	Kaimanawa Region	
pt	Moawhango Region	
pt	Ruahine Region	
	Maungaharuru District	Hawke's Bay Region
pt	Heretaunga District	Hawke's Bay Region

Reference:

Simpson, P. 1982: Ecological regions and districts of New Zealand—a natural subdivision. *Biological Resources Centre Publication No. 1.*

APPENDIX 18

Glossary of Plant Names

acacia	*Acacia* spp.
apple	*Mains domestica*
apricot	*Prunus armeniaca*
asparagus	*Asparagus officinalis*
avocado	*Persea americana*
barley	*Hordeum vulgare*
barley grass	*Hordeum murinum*
bean	*Vicia faba, Phaseolus vulgaris*
black beech	*Nothofagus solandri* var. *solandri*
blackberry	*Rubus fruticosus*
blue tussock	*Poa colensoi*
boysenberry	*Rubus ursinus* var. *loganobaccus*
bracken	*Pteridium esculentum*
bristle tussock	*Rytidosperma setifolium*
broadleaf	*Griselinia littoralis*
browntop	*Agrostis tenuis*
cabbage	*Brassica* spp.
Californian thistle	*Cirsium arvense*
capsicum	*Capsicum annuum*
carrot	*Daucus carota*
cauliflower	*Brassica oleracea* var. *botrytis*
celery	*Apium graveolens*
cherry	*Prunus avium*
chou moellier	*Brassica oleracea* var. *medullosa*
cocksfoot	*Dactylis glomerata*
Corsican pine	*Pinus nigra*
crested dogstail	*Cynosurus cristatus*
danthonia	*Rytidosperma* spp.
Douglas fir	*Pseudotsuga menziesii*
eucalypt	*Eucalyptus* spp.
feijoa	*Feijoa sellowiana*
fennel	*Foeniculum vulgare*
five finger	*Pseudopanax arboreus*
flax	*Phormium tenax*
foxglove	*Digitalis purpurea*
glasswort	*Sarcocornia quinqueflora*
gorse	*Ulex europaeus*
grape	*Vitis vinifera*
Hall's totara	*Podocarpus hallii*
hard beech	*Nothofagus truncata*
hard tussock	*Festuca novae-zelandiae*
hinau	*Elaeocarpus dentatus*
kahikatea	*Podocarpus dacrydiodes*
kaikawaka	*Libocedrus bidwillii*
kamahi	*Weinmannia racemosa*
kanuka	*Leptospermum ericoides*
karaka	*Corynocarpus laevigatus*
kiwifruit	*Actinidia chinensis*
kumera	*Ipomoea batatas*
lancewdod	*Pseudopanax crassifolius*
larch	*Larix decidua*
lettuce	*Lactuca sativa*
lodgepole pine	*Pinus contorta*
lucerne	*Medicago sativa*
lupin	*Lupinus* spp. usually *L. arboreus*
mahoe	*Melicytus ramiflorus*
maire	*Nestegis cunninghamii*
maize	*Zea mays*
manuka	*Leptospermum scoparium*
marram grass	*Ammophila arenaria*
matai	*Podocarpus spicatus*
mid-ribbed snow tussock	*Chionochloa pallens*
miro	*Podocarpus ferrugineus*
monoao	*Dracophyllum subulatum*
mountain beech	*Nothofagus solandri* var. *cliffortiodes*
mountain toatoa	*Phyllocladus alpinus*
nectarine	*Prunus persica* var. *nectarina*

ngaio	*Myoporum laetum*
nikau	*Rhopalostylis sapida*
nodding thistle	*Carduus nutans*
oat	*Avena sativa*
onion	*Allium cepa*
passionfruit	*Passiflora edulis*
pea	*Pisum sativum*
peach	*Prunus persica*
pear	*Pyrus communis*
pingao	*Desmoschoenus spiralis*
pink pine	*Dacrydium biforme*
plum	*Prunus domestica, P. salicina*
poplar	*Populus* spp.
potato	*Solanum tuberosum*
praire grass	*Bromus willdenowii*
pukatea	*Laurelia novae-zelandiae*
pumpkin	*Cucurbita maxima*
ragwort	*Senecio jacobaea*
rape	*Brassica napus* ssp. *oleifera*
raspberry	*Rubus idaeus*
rata	*Metrosideros robusta*
ratstail	*Sporobolus africanus*
raupo	*Typha orientalis*
red beech	*Nothofagus fusca*
red clover	*Trifolium pratense*
red tussock	*Chionochloa rubra*
rewarewa	*Knightia excels a*
rimu	*Dacrydium cupressinum*
ring fern	*Paesia scaberula*
ryegrass	*Lolium* spp.
sea aster	*Aster subulatus*
sea rush	*Juncus kraussii*
silver beech	*Nothofagus menziesii*
silver tussock	*Poa laevis*
spinifex	*Spinifex hirsutus*
strawberry	*Fragaria* x *ananassa*
subterranean clover	*Trifolium subterraneum*
swede	*Brassica napus* ssp. *napobrassica*
sweet vernal	*Anthoxanthum odoratum*
tauhinu	*Cassinia leptophylla*
tawa	*Beilschmiedia tawa*
timothy	*Phleum pratense*
tomato	*Lycopersicon esculentum*
totara	*Podocarpus totara*
tree fern	*Dicksonia* spp., *Cyathea* spp.
turnip	*Brassica rapa* ssp. *rapa*
tutu	*Coriaria* spp. usually *C. arborea*
variegated thistle	*Silybum marianum*
wheat	*Triticum aestivum*
white clover	*Trifolium repens*
willow	*Salix* spp.
wineberry	*Aristotelia serrata*
winged thistle	*Carduus tenuiflorus*
Yorkshire fog	*Holcus lanatus*

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