



Chapter 1

Introduction

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Background

The Hawke's Bay region is underlain by fine grained, weakly indurated Tertiary marine sediments. Much of the land was cleared of indigenous forest and scrub and converted to pasture before the turn of the century (Guthrie-Smith, 1969). Page and Trustrum (1994) used evidence from sediment cores recovered from Lake Tutira in northern Hawke's Bay to deduce historic rates of sedimentation. They concluded that the conversion of indigenous forest, initially to a fern-scrub combination and more recently to pasture, had increased landsliding and hillslope channel erosion, as well as sheet and tunnel gully erosion.

Numerous plantation forests have been established over the years on the soft rock hill country of coastal Hawke's Bay. Concern has been expressed that harvesting these forests may cause a renewed phase of erosion which, in turn, could adversely effect water quality and quantity.

Local forest industries and the Hawke's Bay Regional Council decided that the most effective method to provide defensible information on these effects was to set up a paired catchment study in a typical coastal hill country environment and to measure the main variables during a cycle of forestry, while using a standard pastured catchment for comparison as a control.

This led to the establishment of the Pakuratahi/Tamingimingi Land Use Study in 1993. The terms of reference were: to quantify the impacts of forest harvesting and re-establishment (Pakuratahi catchment) and pastoral farming (Tamingimingi catchment) on soil erosion and stream water quality in steep coastal Tertiary hill country of Hawke's Bay for the purpose of developing best management practices and policies to sustain water and soil resources while maximising production by:

- measuring soil slip erosion in relation to land use change
- identifying sources and volumes of sediments specific to landforms and land-use and their contribution to streams
- identifying landslide causal factors in relation to geology and soils
- recording changes in stream flow
- quantifying water quality parameters
- identifying environmentally sensitive areas
- characterising in-stream flora and fauna and their habitat.

The participating organisations were restricted to those making financial contributions to the project. These comprised:

- Hawke's Bay Regional Council
- Pan Pac
- Carter Holt Harvey
- Juken Nissho
- Logging Industry Research Organisation (LIRO)
- Landcare Research NZ Ltd.

During the course of the project Landcare Research withdrew while LIRO was disbanded. However, Landcare Research, Forest Research (now Ensis), and NIWA provided much of the science through contracts to undertake specific scientific activities. The other main science providers were Massey University and Hawke's Bay Regional Council.

A management committee was established comprising those organisations making financial con-



tributions, and this met annually. Its function was to ensure that the research objectives were achieved by:

- the periodic assessment of research progress and objectives
- facilitating the appropriate management of funds
- addressing potential problems that may hinder specific research objectives
- maintaining the period of research until relative environmental stability was achieved (after harvesting and forest establishment)
- serving as a communication link between industry, regulatory authorities, research organisations, landowners and the public.

An initial time frame of 10 years from 31 June 1993 was identified for the project. In 2002 the committee recommended the project be extended for a further three years until June 30th 2006 to enable the replanted forest to achieve canopy closure over a majority of the area. This proposal was put to each of the funding organisations and approved. Thus the project has continued until 2006.

The committee has met each year, and an annual report was provided to each of the funding organisations.

As significant pieces of work have been completed these have been published in the scientific literature, following approval by the committee. These publications are included in the reference list at the end of this chapter.

Choice of catchment

The objective was to find two catchments of similar size with land owners who would permit flow and rainfall to be monitored over the period of the project.

The criteria for catchment selection were that they had to be:

- close to Napier from where the monitoring would be undertaken
- of similar size
- close to each other
- of similar geomorphology, geology, and climate
- readily accessible.

Based on these criteria, the Pakuratahi and Tamingimangi catchments were chosen for the study. They are located 18 km north of Napier and 3km inland from the coast. These two adjacent catchments met all of the requirements listed above. The Pakuratahi catchment was owned by Pan Pac Forests Ltd and comprised *Pinus radiata* of uniform age ready for harvesting in 1998, while the slightly larger Tamingimangi catchment was in two blocks and remained in traditional sheep/beef grazing regimes for the duration of the project.

Catchment characteristics

Physical appearance

The combined catchment area is 1574 ha (Fransen & Brownlie, 1996). The two catchments are defined by the topographic divide and the approximate location of the weir on the Tamingimangi, and the intersection of the main north draining tributary and southern-most west draining tributary of the Pakuratahi stream below the Burbury Road culvert. The catchment areas are 795 ha, and 774 ha respectively. The catchment area behind the Pakuratahi weir is 345 ha. They slope to the east from a high of 355 m asl to 30m asl at the Tamingimangi weir and 18 m at the Pakuratahi weir. Both catchments contain flat to gently rounded ridge tops with steep side slopes. The Pakuratahi is the steeper, having more deeply incised valleys with almost 60% of the slopes over 20°, compared with 50% for the Tamingimangi.



Geology

The underlying bedrock is less than two million years old and is part of a series of sedimentary rocks extending in a 30-50 km wide by more than 150 km long coastal belt. Grindley (1960) and Haywick et al (1991) broadly mapped and described the rocks in the catchments. Lithologies range from greywacke conglomerate, silica-rich and shelly sands or sandstone, shelly limestone, to mudstone ('papa') deposited in terrestrial and marine environments.

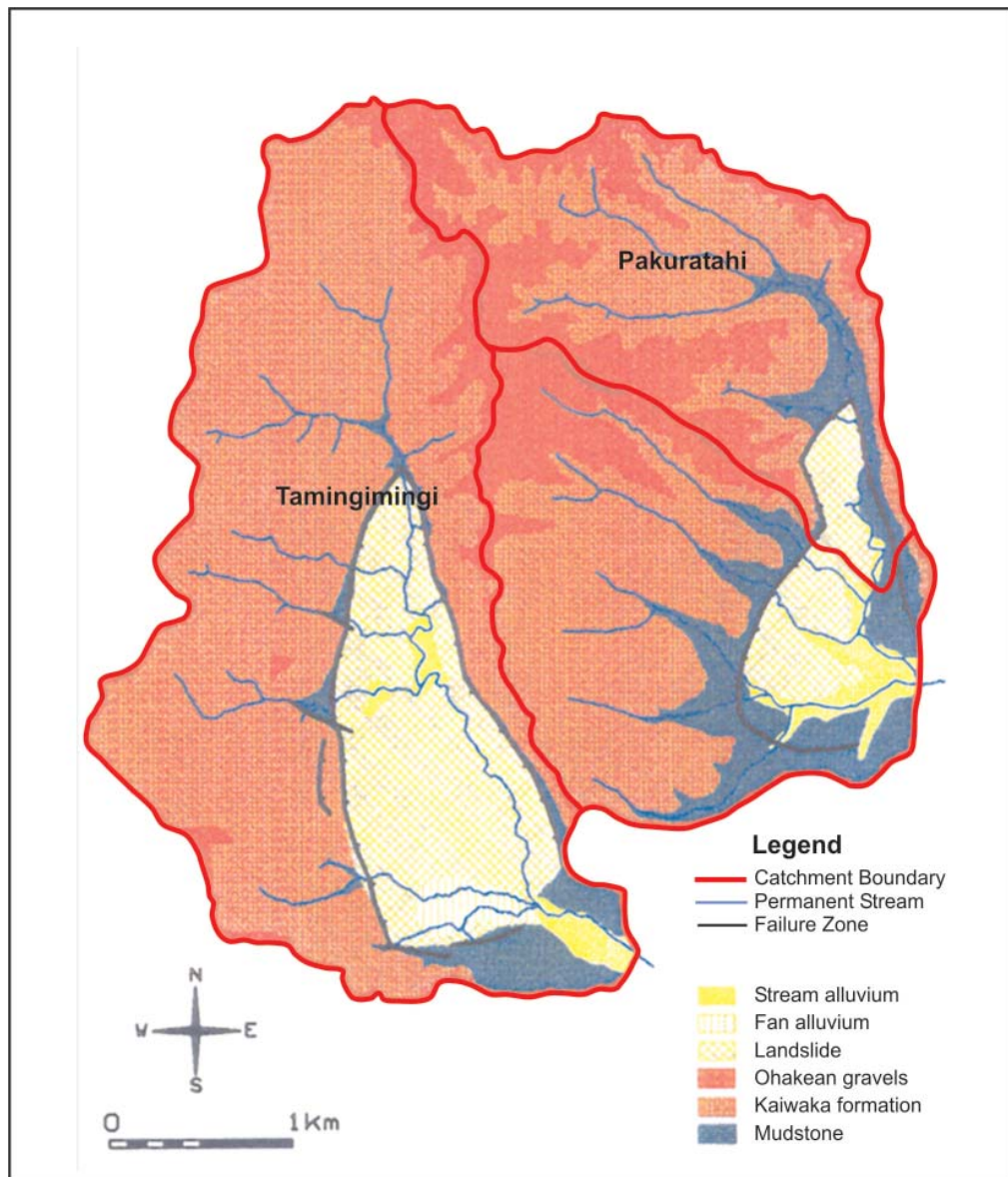


Figure 1. Underlying geology of the Tamingimingi and Pakuratahi catchments (from Fransen & Brownlie, 1996)

The dominant geological formation is the Kaiwaka Formation which is up to 100 m thick and varies markedly in its resistance to erosion (Fig. 1). The base of the formation is recognised by limestone escarpments and small bluffs that outcrop at various levels on upper slopes. Between the limestone members are weak sand/sandstone beds 20-30 m thick, and thin (5-10 m) layers of mudstone. Groundwater seepage occurs at or near the contact with the impermeable mudstones and porous sands. These are important sources of streamflow especially during dry spells. Soil slips are common at these sites.



Two major mudstone formations, the Devil's Elbow and Te Ngaru Formations dominate the middle and lower catchment geology and are older than the Kaiwaka Formation. These much thicker (20-30 m) mudstone formations are separated by about 10 m of poorly exposed shelly sands of the Waipatiki Formation.

Alluvial greywacke (Ohakean) gravels overlie the Kaiwaka Formation on upper slopes and ridge tops. They are extensive in the Pakuratahi catchment but are restricted to the northern part of the Tamingimangi catchment. The gravels vary in thickness due to erosion during and since the last glaciation about 20,000 years ago. On Gardener Road (Pakuratahi catchment east boundary), pumiceous ash beds (related to c. 60,000 year old volcanic deposits) separate the gravels. Also at this locality Oruanui Ash (c.22,000 years old) overlies the gravels. During glacial times, deposition of these gravel beds over extensive flood plains occurred throughout Hawke's Bay.

Tectonic movements during the last 60,000 years elevated the alluvial and marine strata to form a gently (2-10°) eastward tilted landmass that extends along the Hawke's Bay coastal hill country area. Large-scale (10-100 ha) bedrock landslides in the (Rocky Basin) Tamingimangi and Pakuratahi catchments (Terrace Road) predate ash deposits aged about 3,500 years. The landslides form subdued rolling terrain approximately 80-200 m above sea level. Large blocks of Ohakean gravels, Kaiwaka Formation and older mudstone formations comprise the body of the landslide formation. Orientation of these slumped blocks varies considerably with bedding plane dips of up to 74°.

Soils

Soil parent materials are derived from the weathering, erosion and deposition of the bedrock materials, and rhyolitic airfall deposits (tephra) from the Taupo Volcanic Zone. Pohlen et al., (1947) mapped the yellow grey earths (Pallic soils) in the study area as Crownthorpe, Tangoio and Mata-piro sandy loams. These soils may have hard pans that can impede drainage.

Fransen & Brownlie (1996) found that soil types are associated with the specific landforms within the catchments, which assists in their general classification (Fig. 2). The main soil classes were Recent soils (weakly developed soils) and Melanic soils (well structured, dark soils associated with limestones). Recent soils were sub-divided into Tephric and Orthic types.

The Tephric soils are developed on in-situ tephra erupted from the Taupo Volcanic Centre. The Taupo Tephra Formation (c.1,500 yrs BP) and Waimihia Tephra Formation (c.3,500 yrs BP) (Froggart & Lowe, 1990) drape the upper ridges with some remnants existing on the steeper side slopes. The deposits extend into the nearby Tangoio Conservation Reserve to the northeast (Eyles, 1971). The crumb to fine nutty structured sandy loam topsoils are commonly 200-400 mm thick, overlying 500-900 mm thick pale coloured sandy Waimihia Ash. This horizon commonly mantles an eroded surface formed mainly on Kaiwaka Formation sand, and less often on Ohakean gravels and loess (buried Pallic soils), and older volcanic ash beds.

Orthic soils are developed on mixed tephric and bedrock materials (Ohakean gravels, alluvial fan, talus slopes and colluvium). On the steep slopes, topsoils are thin and contain mixed soil and rock materials resulting from mass movement processes.

Rendzic Melanic soils are typically found on the lower slopes at similar levels to the cliff forming Kaiwaka Formation limestone. These soils may also occur at higher levels where thin limestone units are locally present. They are dark brown, nutty structured soils directly developed on limestone.

The fluvial Recent soils of the valley bottoms comprise layers of rich organic material, slip debris and alluvium. They are well preserved in the gentle gradients of valley heads and wide floodplains in the lower reaches, but are infrequent or absent along the middle steeper reaches.

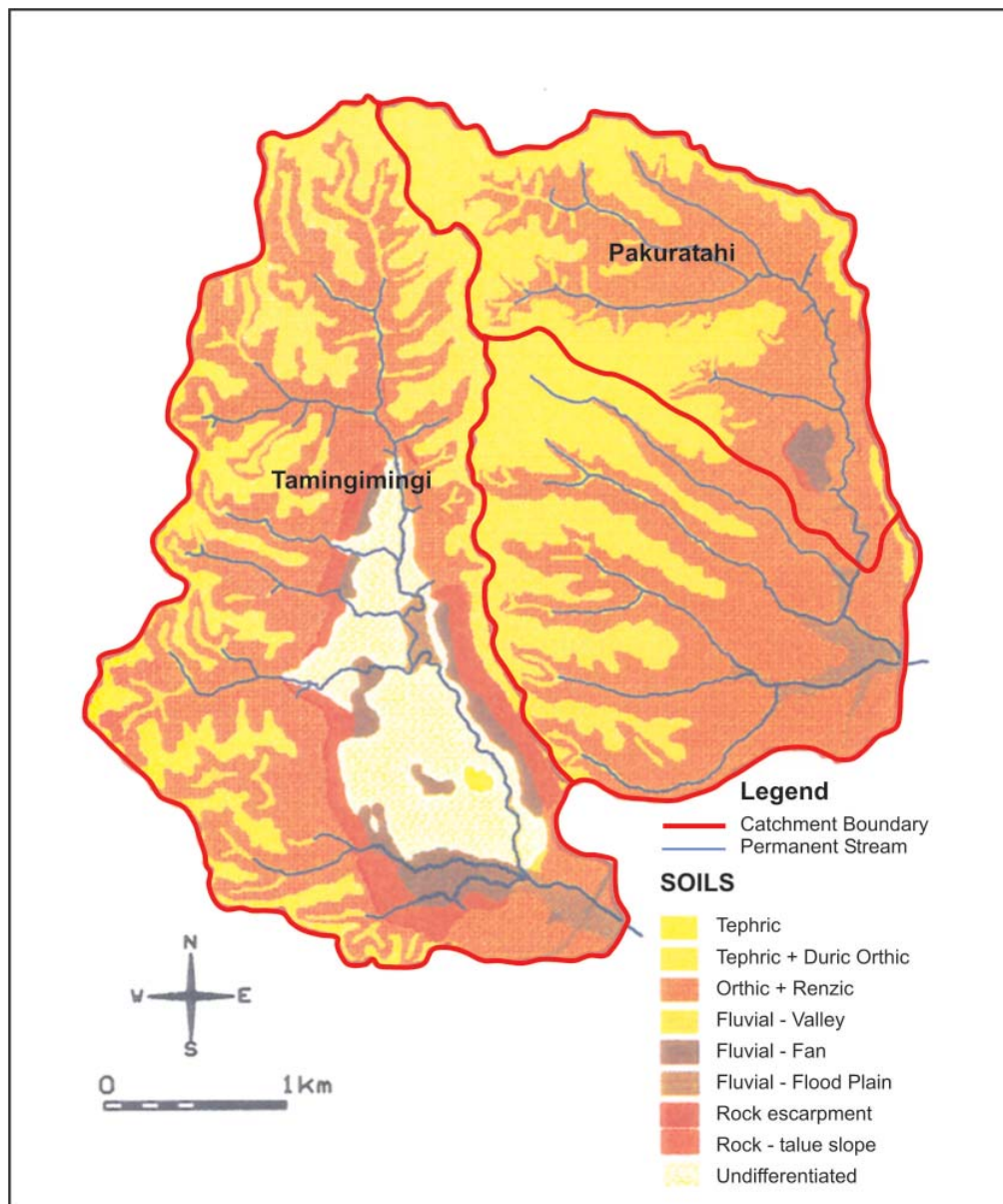


Figure 2. Soil map of the Tamingimingi and Pakuratahi catchments (from Fransen & Brownlie, 1996)

Climate

The Hawke’s Bay climate is one of extremes. The region is prone to droughts but is also subject to cyclonic storm events originating from the tropics. Fortunately both are relatively rare events. Cyclonic storms typically last for about three days but their effects may be felt for decades. Cyclone Bola, which occurred in 1988, is a case in point. Droughts are, by definition, much longer events but their effects are insidious. Besides the immediate effects of prolonged dry periods there is a tendency for soil moisture levels in Hawke’s Bay to decline to low levels and remain low, although rainfall and river levels may return to normal. The project has recorded the recently identified phenomenon of the inter-decadal Pacific Oscillation. This is reflected in a shift from dry conditions through the 1980s and mid 1990s to predicted wetter conditions since about 1998.

The mean annual air temperature for Tangoio, 5 km north of the catchments, is 13.3°C (February



18.0°C and July 8.4°C) (New Zealand Meteorological Service, 1983). The mean annual rainfall (1951–1980) at Tangoio is 1501 mm, of which 54% falls in the winter half year of April to September (New Zealand Meteorological Service, 1983). The mean annual rainfall for Napier (1900–1980) is 824 mm. Annual rainfall variability is high. At Tangoio for example, the lowest recorded annual total is 966 mm, and the highest is 2496 mm. Droughts are common in spring and summer.

The climate of the Tamingimangi and Pakuratahi catchments reflects that of the wider region. Since the project was initiated in 1993 the catchments have experienced significant droughts in 1995 and 1998, as well as a number of major storm events, fortunately not of the size of Bola. Rainfall in the catchments has typically been in the order of 1100 mm a year, with a range from 867 to 1430 mm.

Vegetation

The indigenous vegetation of the study area is difficult to accurately describe as little remains. Landcare Research, in their Predicted Potential Natural Vegetation Map of New Zealand (Landcare Research 2003) identified two forest classes; Rimu/Tawa – Kamahi, and Kahikatea - Pukatea – Tawa. Guthrie-Smith (1969) wrote that “fire played a central role in the destruction of forests with more recent fallen logs as the distance from the coast increases.” He believed there was a period when the whole area was covered with forest; “bush of a lesser size and more ephemeral nature possessing the eastern coastal belt, timber of great girth and of a more durable character flourishing inland. Consequent on forest fires a gradual retreat inland of these woodlands has been traced.” Grant (1996) considers that wind and fire have had major impacts on the extent of forests. It is likely that dense forests occurred in the more sheltered environments. Such an example is the Pakuratahi bush, a 4 ha remnant on Fisher’s property at the lower end of the Tamingimangi catchment. This contains kahikatea and matai with associated species such as pigeonwood, titoki and mahoe. Tawa is not present. Mature trees often have shattered tops. There are no examples of original forest on the more exposed tops in the catchment headwaters.

History of land-use

Much of the original forest cover in the Hawke’s Bay was subjected to progressive burning by Polynesian settlers from about 1000 AD (McGlone, 1978). This was followed by large-scale scrub and fern clearance and conversion to pasture by European colonists in the mid-to-late 19th Century (Guthrie-Smith, 1969).

According to Fransen & Brownlie (1995), the Tamingimangi catchment was intensively grazed, whereas the Pakuratahi was used primarily for stock grazing for the Waipunga Station. By the 1920s, more of the Pakuratahi was converted to pasture, especially following the allocation of ballot blocks for returned servicemen. Small stands of Matai, Kahikatea, Titoke and Totara in the catchment were milled to provide an income for local land owners. However, subsequent changes in land ownership did not lead to any improvement in pasture condition, and eventually much of the catchment reverted back to scrub. Periodic slip erosion was also a problem. In 1971/72 Carter Holt Harvey planted the catchment in radiata pine, and the area became part of Tangoio Forest.

History of landslip erosion and changes in vegetation cover

The landscape is characterised by erosion scars ranging from those which are bare to those which are fully grassed and only discernable through slight changes in morphology round their margins. Fransen & Brownlie (1995, 1996) used a chronological series of aerial photographs available from 1943 to 1994 and ranging in scale from 1:6,000 to 1:27,000, to map historical slip erosion and



land-use patterns for the two catchments using an analytical stereoplotter linked to GIS software. For the Pakuratahi, their study included all the area down to the southern-most draining tributary of the main Pakuratahi stream below the Burbury Road culvert, amounting to 744 ha. The area of the Tamingimangi included that above the weir (795 ha). Lamason (2005) used a 2004 run (scale 1:20,000).

According to Fransen and Brownlie (1996), in 1943 slip erosion scars covered 20 ha, representing 2.6 % of the catchment (Table 1). The density of slips was greater in the Pakuratahi catchment (296/km²) than in the Tamingimangi catchment (232/km²). The large number of slips appearing on the 1943 photos is believed to be the result of a combination of preceding factors including the removal of large areas of protective scrub, the 1931 earthquake, and a storm in 1938 that produced 229 mm of rainfall in 24 hr (SC&RCC, 1957). The final trigger, however, is thought to have been the “Anzac” storm that occurred between 23 and 25 April that same year, which caused widespread damage throughout coastal Hawke’s Bay (SC&RCC, 1957). This storm produced 692 mm in 4 days at Tutira, 12 km north of the catchments (Fransen, 1998). At this time, land use was predominantly pasture with 17% of the Pakuratahi catchment and 9% of the Tamingimangi catchment in indigenous vegetation.

Land Use	Pasture (ha)	Indigenous (ha)	Amenity (ha)	Young Forest	Mature Forest	Road
Tamingimangi	725.4	72.2	1.2	-	-	-
Pakuratahi	643.4	130.1	1.0	-	-	-

Slips	Number	Total Area (ha)	% Area	Density (No./km ²)	Average Area (m ²)
Tamingimangi	1850	9.4	1.2	232	50.8
Pakuratahi	2294	10.6	1.4	296	46.2

Table 1. Slip erosion and land use statistics for 1943 derived from analysis of 1943 aerial photos

By 1970, slip erosion affected only 0.06% of the Tamingimangi catchment and 0.01% of the Pakuratahi catchment (Table 2). Lower slip densities in the Pakuratahi catchment may be attributed to the greater area of indigenous vegetation which covered 39% of the catchment. Since 1943, 22% of the Pakuratahi catchment had reverted to indigenous cover. However, in the Tamingimangi catchment, indigenous cover was 2.3% less in 1970 than in 1943. Also recorded were three hectares of pine plantation established in the southern part of the Pakuratahi catchment in 1964 (source: Hawke’s Bay Tribune, 21 March 1995).

Land Use	Pasture (ha)	Indigenous (ha)	Amenity (ha)	Young Forest	Mature Forest	Road
Tamingimangi	748.8	21.7	1.3	26.2	-	0.8
Pakuratahi	116.4	47.4	1.4	594.6	-	14.6

Slips	Number	Total Area (ha)	% Area	Density (No./km ²)	Average Area (m ²)
Tamingimangi	134	0.5	0.06	17	37.3
Pakuratahi	17	0.1	0.01	2	58.8

Table 2. Slip erosion and land use statistics for 1970 derived from analysis of 1970 aerial photos



In 1987, following an extended wet period, Fransen (1998) mapped slip erosion in both catchments. In the forested catchment, which had a stocking rate of 200 stems/ha, there was a higher slip density (131 slips/km²) than that recorded in the pasture catchment (55 slips/km²). He also found that, under 8 year old trees with a stocking rate of 800 stems/ha, the density was only 13 slips/km².

In 1988, high slip densities recorded on pasture land in the Tamingimingi catchment and the upper Pakuratahi catchment were the result of Cyclone Bola in March that year. This storm was responsible for the largest rainfall event in the region since records began in 1894 (620 mm in 3 days). Slips covered 6.5 times more area on a catchment basis in the Tamingimingi catchment (in pasture) than the Pakuratahi catchment with a 17-year old cover of radiata pine over 73% of its area (Table 3).

An additional 6 ha of pine plantation (farm woodlot) was established in the lower Tamingimingi catchment. The Pakuratahi catchment forest area declined as a result of realignment to roads and construction of landings in 1985 (P. Reid, Pan Pacific Industries Ltd., pers.comm.)

Land Use	Pasture (ha)	Indigenous (ha)	Amenity (ha)	Young Forest (ha)	Mature Forest (ha)	Road (ha)
Tamingimingi	841.8	21.9	1.3	6.0	26.2	1.5
Pakuratahi	121.8	46.7	0.1	-	568.0	37.8
Slips	Number	Total Area (ha)	% Area	Density (No.km ²)	Average Area (m ²)	
Tamingimingi	1036	7.3	0.91	130	70.4	
Pakuratahi	171	1.1	0.14	22	64.3	
Pakuratahi	131	0.9	1.53	228	68.7	

Table 3. Slip erosion and land use statistics for 1988 derived from analysis of 1988 aerial photos

In 1989, 38 ha of pasture were planted in pines in the upper Pakuratahi catchment (Table 4). This increased the area in pines within the catchment from 3% (in 1988) to 78%.

The percentage area in slip scars in the Tamingimingi catchment declined about 60% between 1988 and 1994 . This was mainly attributed to the recovery of the scars through pasture re-growth.

Land Use	Pasture (ha)	Indigenous (ha)	Amenity (ha)	Young Forest (ha)	Mature Forest (ha)	Road (ha)
Tamingimingi	841.8	21.9	1.3	6.0	26.2	1.5
Pakuratahi	121.8	46.7	0.1	-	568.0	37.8
Slips	Number	Total Area (ha)	% Area	Density (No.km ²)	Average Area (m ²)	
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Pakuratahi	171	1.1	0.14	22	64.3	
Pakuratahi (runner)	131	0.9	1.53	228	68.7	

Table 4. Slip erosion and land use statistics for 1994 derived from analysis of 1994 aerial photos and field studies



In January-February 2006, HBRC staff recorded erosion types in the two catchments by locating each scar on colour orthorectified images (taken in 2004, with 0.5m resolution) (Table 5). These data were transferred to GIS using ARCVIEW. Land cover was not recorded.

On 21 and 22 October 2005, 196 mm rain fell (170 mm on the 21st) at Top Run and 188 mm at Fishers (161 mm on the on 21st) with the highest intensity being 19.5 mm/hr. Recent scars are believed to have resulted from this event. In the Tamingimingi, scars providing sediment to waterways were clustered around the streams. Often these scars were in the more densely vegetated riparian zone where ground cover was low due to grazing. However, the main sources of sediment appeared to be from stream bank erosion due to undercutting and consequent bank collapse. In contrast, the very few recent slip scars in the Pakuratahi were either on 40° plus slopes not planted in trees or adjacent to roads, resulting from fill collapse or from bank and roadside scour. No stream bank erosion was observed.

Slips	Number	Total Area (ha)	% Area	Density (no.km2)	Average Area (m2)
Tamingimingi	155	0.23	0.3	19	15
Pakuratahi	8	0.14	0.004	3	11

Table 5. Slip erosion for 2006 derived from field observations and recorded on 2004 images

The slip erosion sites for 2005 derived from field mapping by Lamason (2006), together with those identified by Fransen & Brownlie (1995) from aerial photographs for 1994, 1988, 1981, 1970, and 1943, are shown in Figure 3.

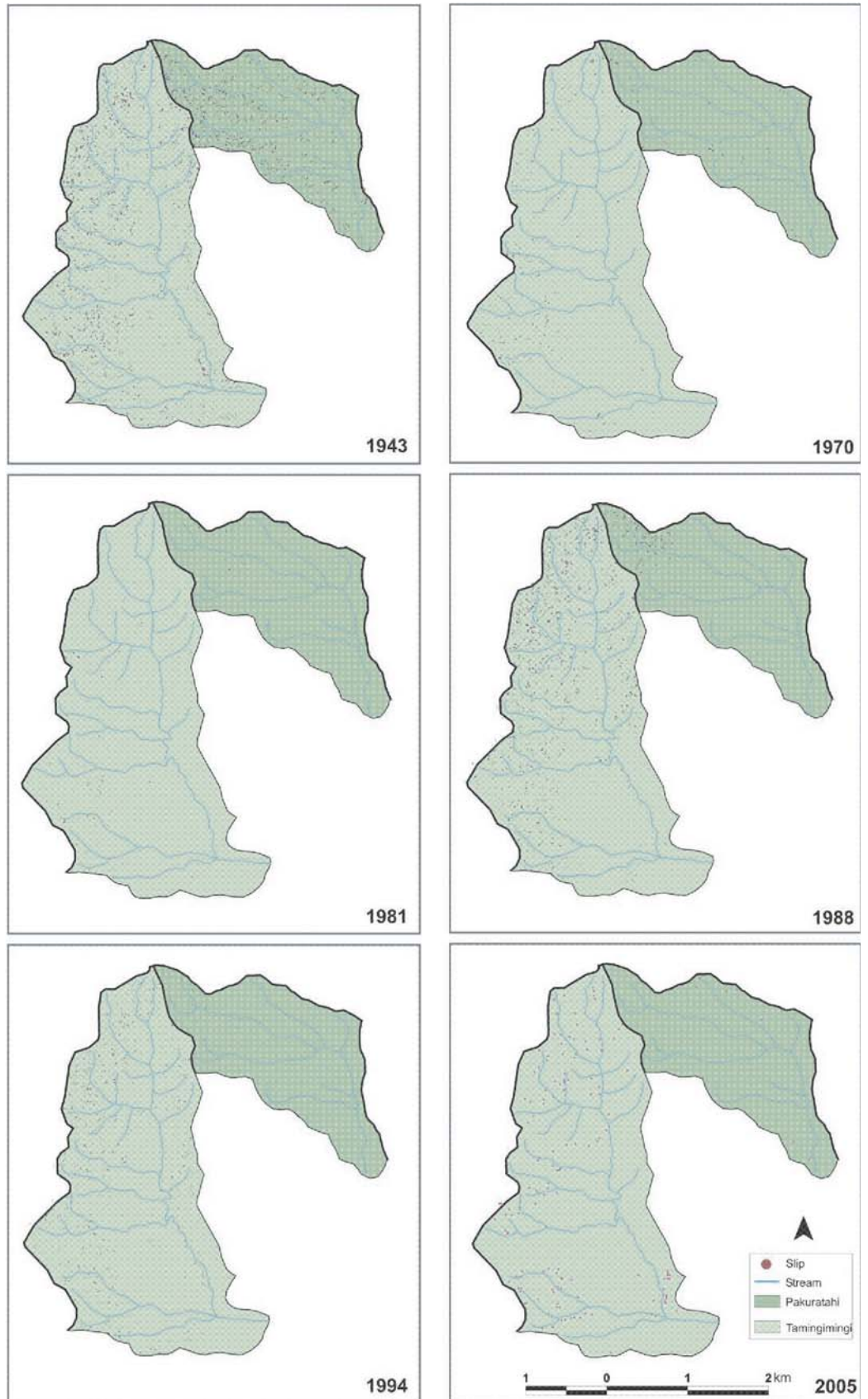


Figure 3. Pakuratahi and Tamingimingi catchments. Slip Erosion 1943, 1970, 1981, 1988, 1994, 2005 (Fransen, Brownlie 1995, Lamason 2006)



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