Chapter 7

Forestry Effects on Channel Morphology and Channel Vegetation

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Introduction

In 1993, a land use study was initiated in the Hawke's Bay coastal hill country to compare the impacts of pastoral farming and pine plantation forestry in two adjacent catchments. The objective of this component of the study was to compare changes in channel morphology and channel vegetation in the Pakuratahi catchment (3.45 km^2) before, during and after harvest with the pastoral Tamingimingi catchment (7.95 km^2). An earlier report by Fransen (1998) compared slips, sedimentation and stream channel profiles in the Pakuratahi and Tamingimingi catchments following storm events in June and July 1997, prior to harvesting of Pakuratahi. A later report by Baillie et al. (2002), documented changes in stream channel morphology, channel substrate, and channel vegetation in the two catchments before and after harvesting of the Pakuratahi. Ecological stream surveys undertaken by Massey University in conjunction with the channel morphology assessments are reported separately in Death (2002), Death et al., (2003), and Chapter 8 of this report. No channel morphology surveys were carried out in 2001-2004 but a final assessment was made in 2005 (Baillie, 2005).

Methods

In 1996, six stream sites were selected for monitoring channel morphology, three each in the pasture (Tamingimingi) and pine plantation (Pakuratahi) catchments (Fig. 1). The stream sections were straight to slightly meandering, with stream banks comprising alluvium. Two of the Pakuratahi sites, P1 and P2, were located on separate first order tributaries in the headwaters of the catchment while site P3 was at the base of the forest catchment about 200 m upstream of the Forest Glade weir. The Tamingimingi sites, T1, T2 and T3 were, in contrast, longitudinally placed along the main branch of the Tamingimingi Stream (Fig. 1). The lower Tamingimingi stream site (T3) defines a similar catchment area as P3, for comparison. The other two pastoral stream sites were located upstream and define larger catchment areas compared to the upper Pakuratahi stream sites. Mean channel widths at the six sites ranged from 2.0-3.0 m (Fransen, 1998).

In January 1997, at each stream site, ten transects were installed along a section of stream (length ranged from 56-106 m) to measure channel cross-sectional profiles. At P3 nine transects were available after the loss of one transect to slip debris in July 1997. Cross-sections were measured based on the sag tape procedure of Ray and Megahan (1979). A tape was suspended between steel stakes driven into the bank on either side of the channel (Fig. 2).

Vertical measurements of the channel profile, substrate and vegetation were made at 0.2 m intervals across the active stream zone using a survey staff, and at intervals of less than 1 m elsewhere. However, inadvertent errors in tape height attachment, disturbances to stakes (stock, ground settling, harvest activities, flood debris) and sediment deposition around the stake did occur and measurements with unresolvable errors were omitted from analysis. Channel substrate and vegetation were classified according to the categories in Table 1. Eight surveys were undertaken at all sites during the period January 1997-January 2000 with additional post-harvest surveys in P2 and P3. Further details on methodology are available in Baillie et al. (2002).

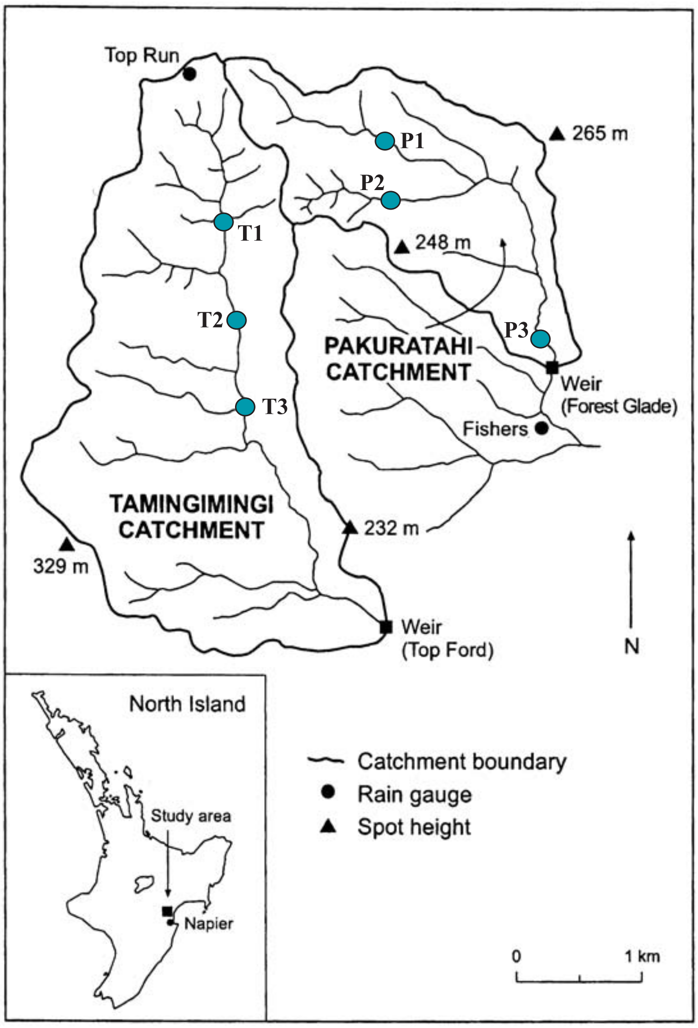


Figure 1. Location of the Pakuratahi and Tamingimingi catchments and study sites (from Fahey and Marden, 2000).

Regular maintenance of the cross-sectional stakes was required to maintain the accuracy of the channel profile measurements, which are measured to the nearest millimetre. The lack of trial maintenance in the period 2001-2004 precluded re-measurement of channel profiles in the 2005 survey (Baillie, 2005). In addition, vegetative regrowth, particularly in the headwater sites of the Pakuratahi catchment made site and stake relocation difficult. Channel substrate was re-assessed along 10 transects at each site in the Pakuratahi and Tamingimingi catchments using Leopold's (1970) pebble count procedure, and the same substrate categories as previous surveys (Table 1).

Substrate class
1 – silt/sand (SI/SA) <2mm
2 – small gravel (SG) 2-8mm
3 – small medium gravel (SMG) 8-16mm
4 – medium large gravel (MLG) 16-32mm
5 – large gravel (LG) 32-64mm
6 – small cobble (SC) 64-128mm
7 – large cobble (LC) 128-256mm
8 – boulder (B) >256mm
9 – bedrock
10 – small woody debris (SWD)<10cm
11 – large woody debris (LWD)>10cm
12 – cow pat

Vegetation Type
1 - rock
2 - bare
3 – litter
4 – annuals
5 – grass
8 – ground ferns
9 – low shrub
15 – watercress
16 – moss
17 – algae
18 – slash

Table 1. Codes used to classify substrate and vegetation; only pertinent vegetation codes are listed.

Vegetation was visually assessed along each transect to the nearest 5% using the same classes as in previous surveys (Table 1). Representative photos were taken at each site (Appendix 2). Methodologies were sufficiently similar to compare channel substrate and channel vegetation with previous surveys.

Figure 2. Cross-section at T3 (pasture site) before and after the July 1997 storm .

Figure 2. Cross-section at P3 (pine site) before and after the July 1997 storm (Fransen, 1998).

Analysis

To measure changes in streambed level, differences in vertical height between two survey periods were calculated for each cross-sectional profile and averaged to give the mean change in streambed level for each site. Substrate and vegetation were summarised by class for each cross-section and percent composition calculated for each of the 6 sites for each survey period. Channel morphology profiles, substrate, and vegetation composition were analysed using a two-way analysis of variance (ANOVA) followed by a 5% least significant difference (LSD) test to determine any significant changes ($P \leq 0.05$) between each survey for each site. Where transect numbers were inconsistent between measurement dates, particularly at the Pakuratahi sites after harvest, differences were investigated with a two-way ANOVA using SAS (version 8.0) with Least Squared Means adjusted for the differing sample size. Substrate median particle size was calculated using the mid-point values of the size classes, bedrock being assigned a size of 400 mm for calculation purposes (Quinn and Hickey, 1990). In the 2005 survey, an unpaired t-test was used to compare median particle size between the two catchments. Substrate and vegetation composition were analysed using a two-sample t-test to determine any significant changes ($P \leq 0.05$) between the 2000 and 2005 surveys for each site.

Results

Channel profile

All three sites in the Tamingimingi (pasture catchment) experienced significant channel scour following the storm of July 1997 ($P \leq 0.05$); stream bed levels dropped by 56 mm, 49 mm, and 51 mm respectively at T1, T2 and T3 (Fig. 3). This was followed by a period of channel aggredation, peaking between January and April 1999. Between April and July 1999, bed levels dropped significantly at all three sites. The channel remained relatively stable for the remainder of the survey period, although there was some aggradation at T2 following the January 2000 storm. Although no measurements were taken in 2005 (see Methods), there appeared to be relatively little change in channel morphology at the Tamingimingi sites. Channel banks were stable although some channel bank slumping was observed at T1 and T3 (Appendix 2).

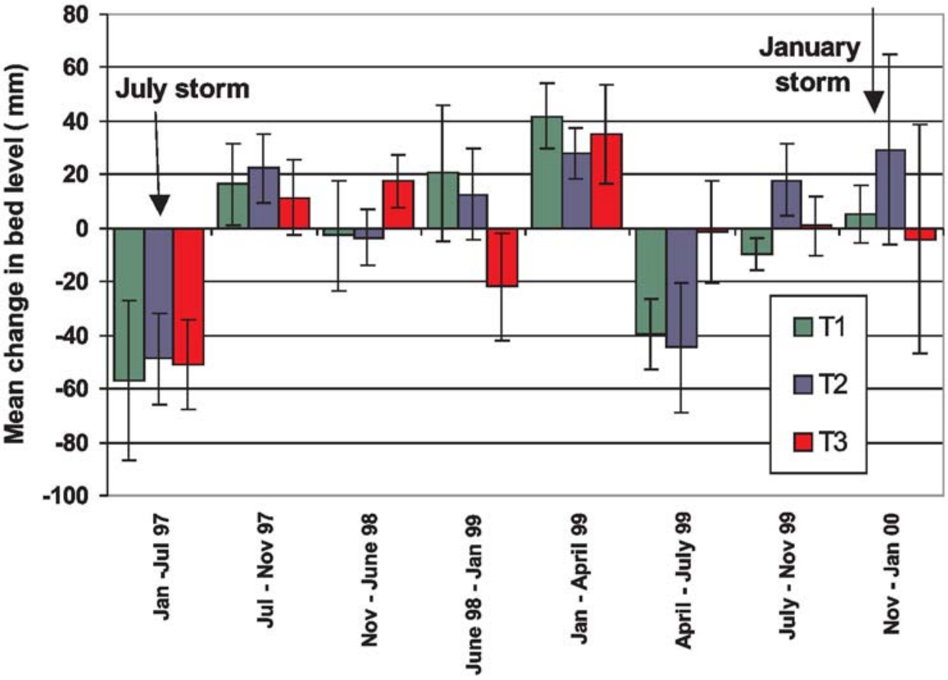
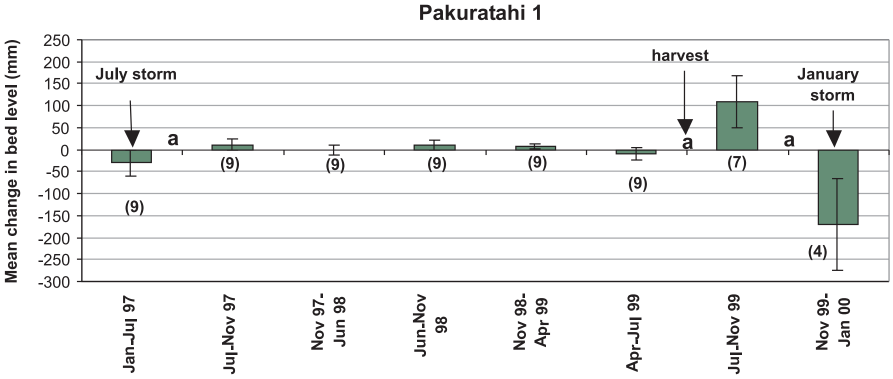


Figure 3. Channel profile changes in the three Tamingimingi sites (error bars = ± 95%CI).

In the Pakuratahi (pine plantation) catchment, the two storms in July 1997 and January 2000, and harvesting operations had the greatest impact on channel profiles with relatively little change in bed levels in the intervening periods (Fig. 4). The July 1997 storm resulted in channel scouring in the headwaters of the Pakuratahi at P1 and P2 (30 mm and 48 mm respectively), with channel aggradation in the lower part of the catchment at P3 (40 mm) (Fig. 4). There was a period of deposition in the stream channel at all three sites after harvest (significant at P1 and P2), followed by a drop in bed level (significant at all three sites). After the January 2000 storm, P1 recorded a significant drop in bed level, in contrast to P2 and P3.

At the time of the 2005 survey, channel banks were stable at all three sites in the Pakuratahi catchment. Stream channels had partially filled with sediment and lacked a defined channel structure at P1 and P2 (Appendix 2). Surface stream flow was intermittent along most of the channel at P1 and parts of the channel at P2. Conversely P3 has maintained a well-defined entrenched channel throughout the survey period (Appendix 1).



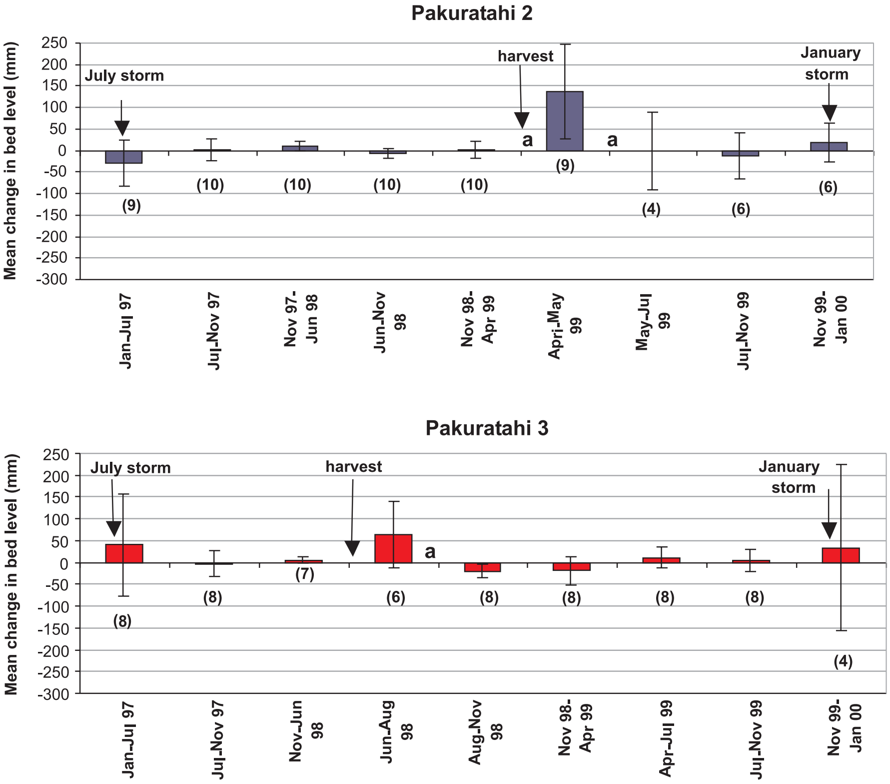


Figure 4. Channel profile changes in the Pakuratahi sites (± 95%CI). Note the additional surveys at P2 and P3 following harvest. ( ) = sample size. ‘a’ denotes a significant change (P£ 0.05) in bed level between surveys.

Channel substrate

Silt/sand and small gravels dominated substrate composition at all three sites throughout the survey period (1997-2005) in the Tamingimingi. Bedrock was also a significant component of the channel substrate (Fig. 5). Following the July 1997 storm there were significant decreases in the proportion of silt/sand at T1 and T3 and increases in the proportion of boulders at all sites, resulting in increased median particle size (Fig. 7). All sites showed a significant increase in the proportion of sand/silt in the June 1998 survey (Fig. 5), with a corresponding decrease in median particle size (Fig. 7). Substrate composition varied through to November 1999, with some significant changes at individual sites, but no discernable pattern was detected across all three sites. Similar to the July 1997 storm, the proportion of sand/silt dropped significantly at sites T1 and T3 after the January 2000 storm, increasing median particle size. Substrate composition was similar at all sites between the 2000 and 2005 surveys, but an increase in median particle size was noted at T2.

Similar to Tamingimingi, sand/silt was the most common substrate type at all three sites in the Pakuratahi (Fig. 6). The proportion of sand/silt increased significantly at P1, decreased significantly at P2 but showed no significant change at P3 after the July 1997 storm (Fig. 6). In the following survey period, the proportion of sand/silt decreased significantly at P1 and P3. Harvesting resulted in an influx of woody debris at P1 and P2 (Fig. 6) and a significant decrease in the proportion of silt/sand at P2. The proportion of sand/silt decreased significantly at P1 after the January 2000 storm but there was little change in substrate composition at the other two sites.

Between 2000 and 2005, the proportion of silt/sand increased significantly and median particle size decreased at P1 (Figs. 3 & 4), but remained similar at P2 and P3. Sand/silt levels were higher in the Pakuratahi compared to Tamingimingi, particularly in the headwater sites. Woody debris was still present in the streams channels at P1 and P2 although much of it was covered with vegetation

and silt. While there were some changes in median particle size at the Pakuratahi sites throughout the survey period, there were none of the more dramatic changes recorded at the Tamingimingi sites following the July 1997 storm (Fig. 7).

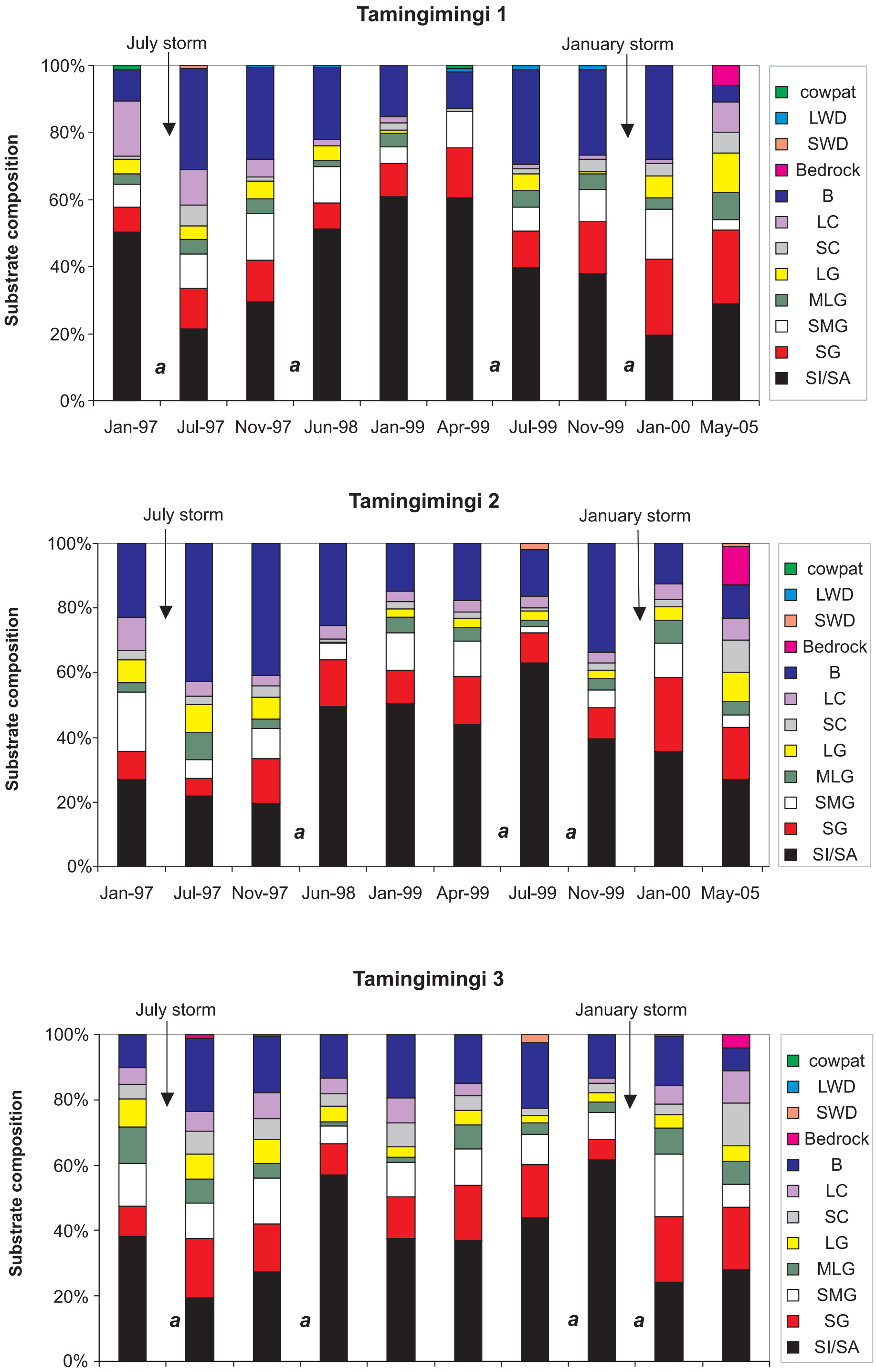


Figure 5. Substrate changes in the Tamingimingi sites. 'a' denotes a significant change (P≤ 0.05) in percentage sand/silt between surveys.

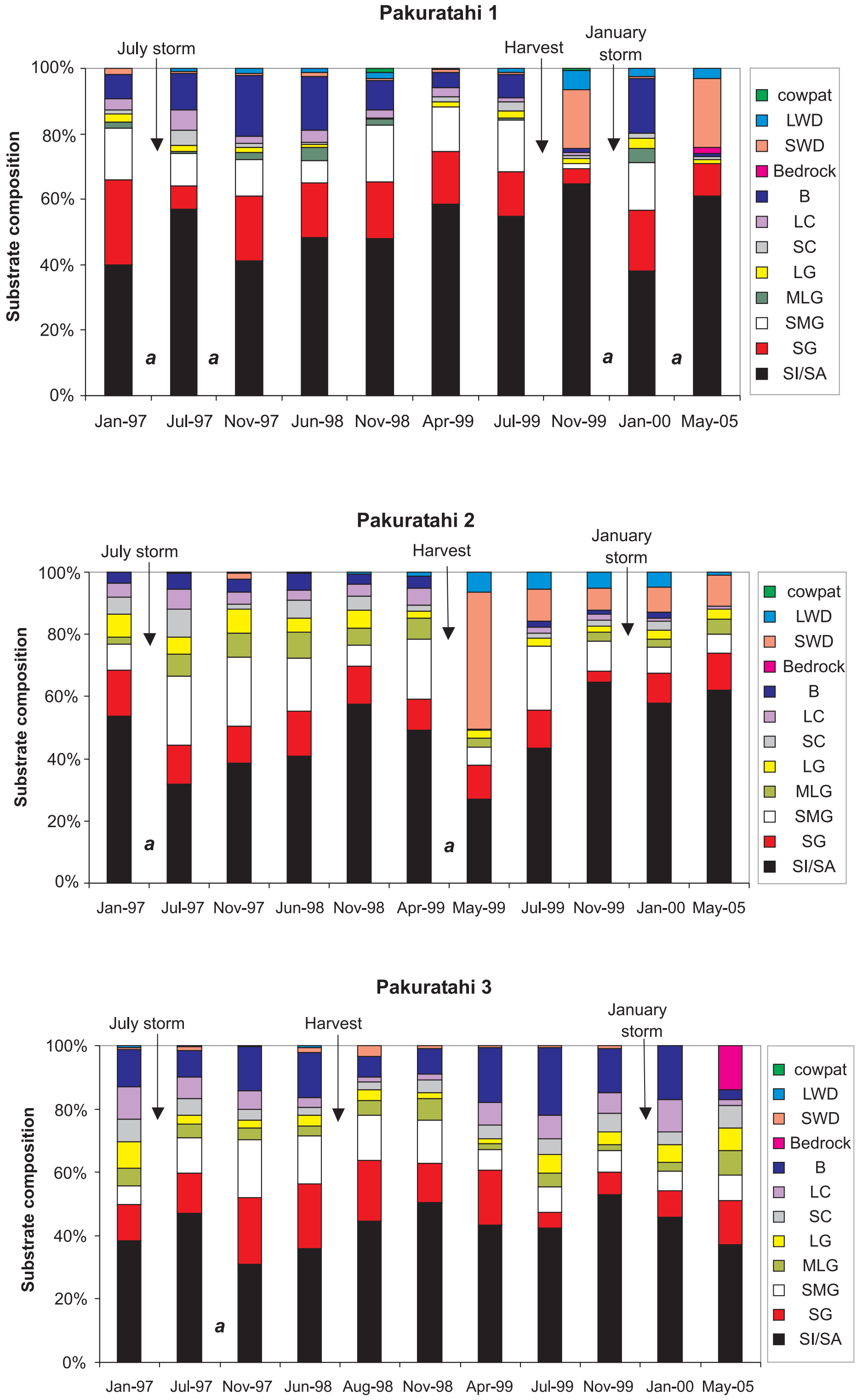


Figure 6. Substrate changes in the Pakuratahi sites. ‘a’ denotes a significant change (P£ 0.05) in percentage sand/silt between surveys.

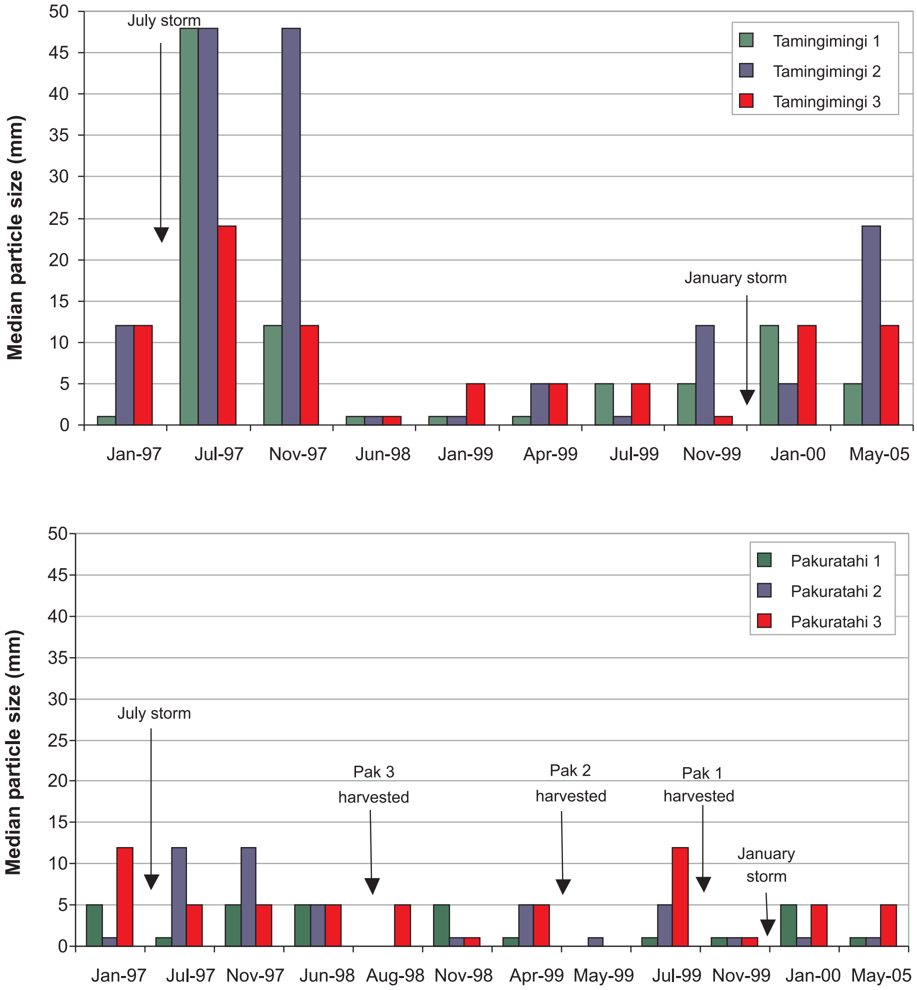


Figure 7. Comparison of median particle size between the Tamingimingi and Pakuratahi catchments. Excludes SWD, LWD and cowpats.

Channel vegetation

In the Tamingimingi catchment, bare ground, watercress and algae were most common in the stream channel throughout the survey period. The most significant vegetation change occurred after the July 1997 storm, removing vegetation and leaving most (>90%) of the channel floor bare (Fig. 8). This was followed by a significant influx of algae in November 1997, and by June 1998 watercress had re-established in the stream channel. The amount of bare surface increased at all sites between January and April 1999. Algae were the dominant vegetation cover following the January 2000 storm, increasing significantly at T1 and T3. There was a significant increase in bare channel and a significant decrease in algae at all three Tamingimingi sites between 2000 and 2005 (Fig. 8). This could be a reflection of the timing of the 2005 survey in winter when algal growth is less prolific than in summer. Annuals, watercress and grass comprised a small proportion of the vegetation in the Tamingimingi stream channel. Channel banks were covered in grazed pasture with a few sedges and ferns (Appendix 2).

In the Pakuratahi bare ground was most common at all sites, and prior to harvest generally covered a greater percentage of the channel floor than in the Tamingimingi catchment (Fig. 9). The amount of bare ground increased at all sites following the July storm, (significant increase at P1 and P3). Following harvest, logging slash and litter increased at all three sites with a corresponding significant decrease in bare ground. The impact of logging slash on vegetation cover in the Pakuratahi sites was probably understated as some transects were not re-measured when logging slash pre-

vented access to the stream channel. The January 2000 storm removed some of the vegetation that had established in the stream channel at P1 and P3, increasing the area of bare ground. By 2005 there was a notable influx of grass in the stream channel along with a lesser amount of shrubs, ferns and blackberry and a reduction in bare channel in P1 and P2 (Fig. 9, Appendix 2). Channel banks were covered in grass and blackberry with small amounts of ferns and shrubs. At P3 there was a significant increase in bare ground in the stream channel (Fig. 9) with an extensive cover of grasses and sedges along the channel banks (Appendix 1 and 2).

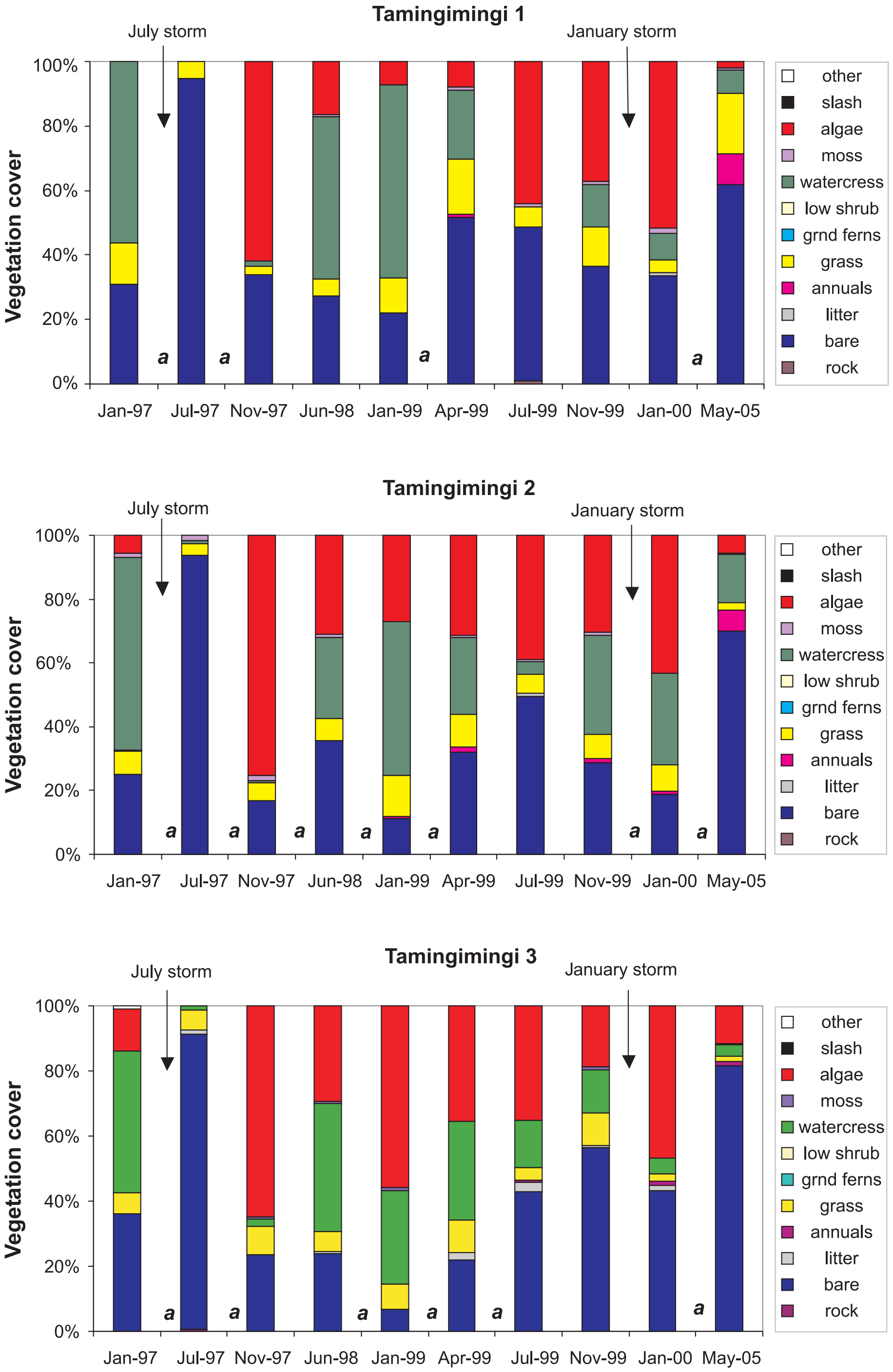


Figure 8. Vegetation changes in the Tamingimingi sites. ‘a’ denotes a significant change (P£ 0.05) in percentage bare ground between surveys.

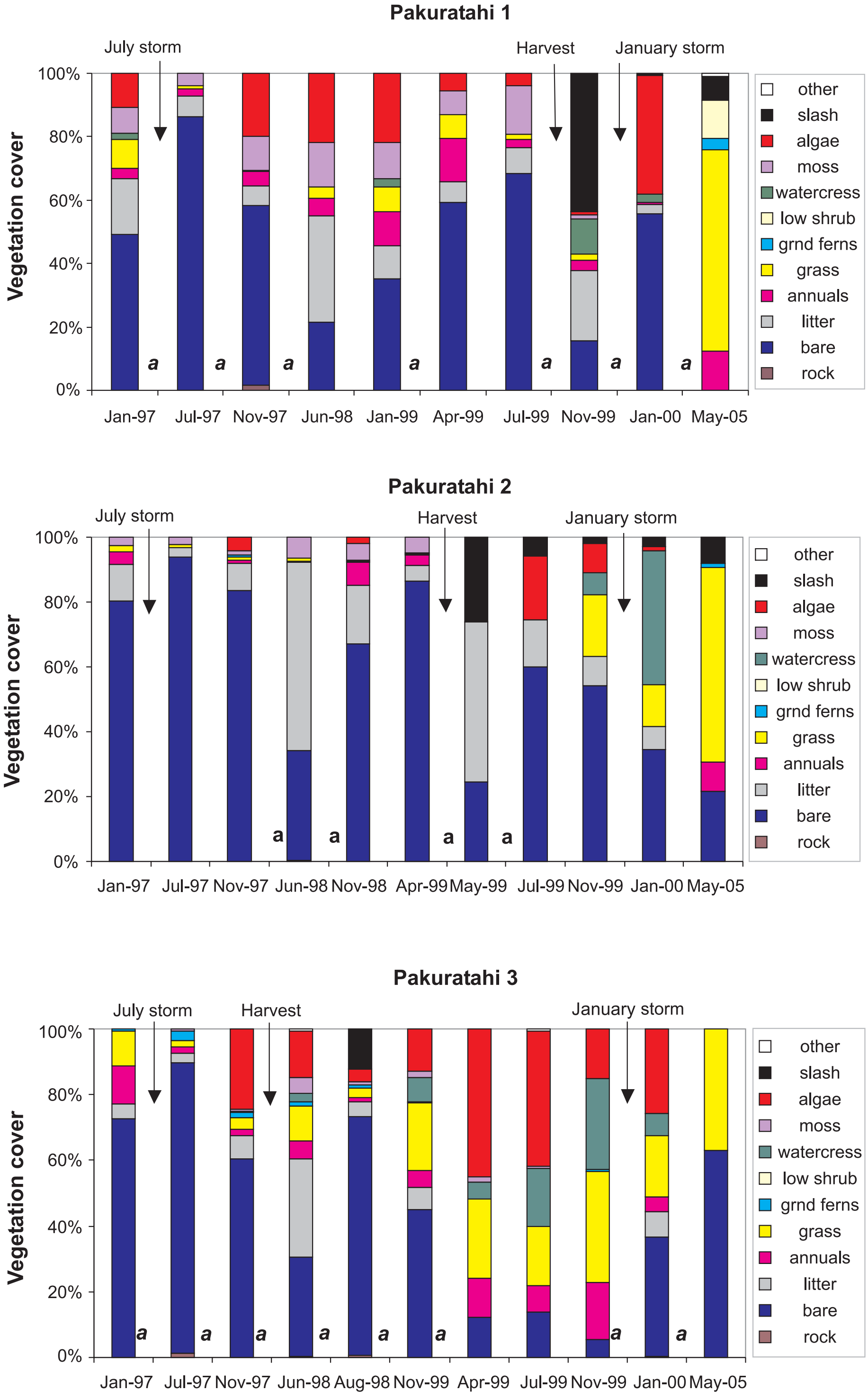


Figure 9. Vegetation changes in the Pakuratahi sites. 'a' denotes a significant change (P£ 0.05) in percentage bare ground between surveys.

Discussion

Tamingimingi (pasture) catchment

Of all the hydrological events that occurred during the survey period, the July storm of 1997 had the most profound effect on the Tamingimingi stream channel. The storm resulted in channel scour at all three sites, removing most of the vegetation and fine material from the substrate, ex-

posing the boulder material and increasing median particle size. Within a year, the channel had recovered; median substrate size was close to pre-storm levels and vegetation had re-established in the stream channel.

The second significant channel scour event in Tamingimingi between April and July 1999 had variable effects on substrate and vegetation in the stream channel, with no noticeable change in median particle size. The reason for this period of scour along the stream channel isn't obvious; the catchment certainly experienced more significant storm events (Eyles, 2001) with relatively little change in the channel profile. Even though the January 2000 storm delivered the highest specific water flow to the Tamingimingi stream channel during the survey period, the storm did not impact on the channel to the extent of the July 1997 storm. The most likely reason for the greater impact of the July 1997 storm was the compounding effect of a catchment already saturated from the previous storm event in June 1997 (Fransen, 1998). At the time of the 2005 survey, the stream in the Tamingimingi pasture catchment appeared relatively stable with little change in substrate or vegetative composition. However, as there was no monitoring of channel morphology between 2000 and 2005 impacts of any significant hydrological events during this period would have been missed.

Pakuratahi (pine) catchment

The July 1997 storm did not have the same impact on the Pakuratahi (pine plantation) catchment as it did in the Tamingimingi catchment and this can be attributed to a number of factors. Lower slip density and lower volumes of slip debris entering the stream along with higher specific water yield in the Tamingimingi catchment most likely contributed to the deeper, more extensive scouring of the stream channel in this catchment (Fransen, 1998). The mature pine cover in the Pakuratahi would have moderated stream runoff and peak flows through higher rainfall interception and evapotranspiration rates compared with the pasture catchment (Fahey and Rowe, 1992). Storm impact varied within the Pakuratahi, scouring the channel in the upper catchment (P1 and P2), and depositing sediment in the lower part of the catchment (P3) with variable changes in substrate composition and median particle size. However, similar to the Tamingimingi, all sites experienced a marked reduction in aquatic invertebrate species richness following the July storm (Death et al., 2003).

The effects of the January 2000 storm on the Pakuratahi catchment were most obvious at the recently harvested P1 site in the upper catchment. Part of the drop in bed level was attributable to localised disturbance from log extraction across the stream channel, but the remainder was the result of channel scour from the flood, mobilising sediment and logging slash. What is surprising is the lack of substrate and vegetation response at the other two sites to an event of sufficient magnitude to mobilise a debris flow down the length of the catchment and into the main stem of the Pakuratahi stream (Fisher's pers. comm.). Flood disturbance to transects reduced the size of the data set available for analysis and may have influenced the results.

Harvesting had a marked impact on stream channels in the Pakuratahi catchment. All sites experienced significant increases in bed level, a result of sediment build up behind the woody debris deposited in the stream channel during harvest, particularly at P1 and P2 where haul direction was across the stream channel. The channel substrate showed little response to harvesting activities at P1 and P3, but levels of fine material in the stream channel decreased at P2. Increased light availability following harvest stimulated vegetation growth in the streams, dominated by algae, watercress, grass and annuals. As the area adjacent to P3 was harvested first, re-establishment of vegetation at this site was more advanced than the other two sites and by January 2000 showed similarities with vegetation cover in the Tamingimingi. Following harvest, aquatic invertebrate community composition changed to closely resemble that found in the Tamingimingi sites (Death et al., 2003).

By 2005, the combination of woody debris and vegetation was trapping and retaining sediment in the headwater streams, infilling channels and disrupting channel flow. In contrast, channel morphology has remained relatively consistent throughout the pre- and post-harvest monitoring period at P3 at the bottom of the catchment (Appendix 1).

Conclusions

When comparing land uses in these two catchments, this study indicates that mature pine plantation was more effective at moderating the effect of storm events on stream channels than pasture. However, harvesting did have a substantial impact on the stream channel increasing sediment levels, woody debris and vegetation cover. A storm event in the immediate post-harvest period had a greater impact on the stream channels in the harvested catchment than the pasture, mobilizing a debris flow down the stream channel. It shows the vulnerability of streams in catchments such as these to significant storm events immediately following harvest especially when logging slash is left in the stream channel.

Increased light levels following harvest have stimulated rapid establishment of vegetation in the stream channels at all three sites The combination of woody debris and vegetation is trapping and retaining sediment in the headwater streams, increasing channel roughness. Along with re-vegetation, over sowing and replanting on the hillslopes, entrapment of sediment in the headwater streams and increased channel roughness are also likely factors contributing to the reduction in sediment yields and peak storm flows in the early establishment phase of the forest rotation. By 2005, post-harvest sediment yields were substantially lower than those from the Tamingimingi catchment (see Chapter 5).

As the trees mature, shade levels will increase and there will be a corresponding die back of channel and bank vegetation and decomposition of logging slash in the Pakuratahi streams. Without this material to retain sediment in the stream channel it is possible that at some point during the rotation this sediment will be mobilised and transported down the channel during high flow events with subsequent downcutting and widening of the stream channel back to its pre-harvest state at the headwater sites (P1 and P2).

The pasture landcover in the Tamingimingi is less effective in intercepting overland flow and with the exception of the immediate post-harvest period, has a flashier hydrology with higher peak flows than the Pakuratahi (Eyles, 2001). With little vegetation to retain sediment in the stream channel, sediment has, and will be readily transported from this system during high flow events. This was reflected in the more dramatic changes in median particle size following high flow events in the Tamingimingi (Fig. 7).

Plantation forests have had a greater impact than pasture in modifying channel morphology characteristics. Channel conditions have undergone marked changes in the Pakuratahi, particularly at P1 and P2 during the harvest and post-harvest phase and it is likely that further channel changes will occur at P1 and P2 as shade levels increase. While the Tamingimingi has experienced changes in substrate composition following sediment flushing events in high flow events and varying levels of algae, it has not experienced the extent of vegetation and channel modification in the headwater sites in the Pakuratahi.

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References

Baillie, B.R. 2005: Channel morphology in pasture and pine catchments, Hawke's Bay, New Zealand – 2005 survey. Ensis Contract Report A15906, Hawke's Bay Regional Council. 19p.

Baillie, B.R.; Fransen, P.; Rodgers, B.; Death, R. 2002: Comparison of channel morphology in pasture and pine plantation catchments, Hawke's Bay, New Zealand. Sustainable Forest Management Report, New Zealand Forest Research Limited. 20p.

Death, R.G. 2002: The effect of land use on invertebrate communities in the Pakuratahi catchment. Massey University, Palmerston North. 32p.

Death, R.G.; Baillie, B.; Fransen, P. 2003: Effect of *Pinus radiata* logging on stream invertebrate communities in Hawke's Bay, New Zealand. New Zealand Journal of Marine and Freshwater Research, 37: 507-520.

Eyles, G. 2001: Pakuratahi land use study 1999-2000 annual report. Hawke's Bay Regional Council.

Fahey, B.D.; Rowe, L. K. 1992: Land use impacts. In: Mosley, M. P. (ed.) Waters of New Zealand. New Zealand Hydrological Society Inc., Wellington. Pp. 265-284.

Fransen, P.J.B. 1998: Slips and sedimentation in mature plantation forest and pastoral hill country, Hawke's Bay, New Zealand. LIRO Report 16 p.

Leopold, L.B. 1970: An improved method for size distribution of stream-bed gravel. Water Resources Research, 6 (5): 1357-1366.

Quinn, J.M.; Hickey, C.W. 1990: Magnitude of effects of substrate particle size, recent flooding, and catchment development on benthic invertebrates in 88 New Zealand Rivers. New Zealand Journal of Marine and Freshwater Research 24: 411-427.

Ray, G.A.; Megahan, W.F. 1979: Measuring cross section using a sag tape: a generalized procedure. General Technical Report INT-47. Ogden, UT: US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 12 p.

Appendix 1:

Changes in channel morphology following harvest at Pakuratahi Site 3

P3 – at harvest 1998

P3 – post-harvest 1998

P3 – post-harvest 1999

P3 – post-harvest 2005

Appendix 2:

Stream channels in the Pakuratahi and Tamingimingi catchments in 2005.

Pakuratahi

Tamingimingi

P1

T1

P2

T2

P3

T3