Riparian Planting for Sediment, Nutrient and Pathogen Management

INTRODUCTION

Waterways in areas of human occupation, agriculture and industry can generate elevated levels of sediment, nutrients (especially phosphorus and nitrogen) and faecal pathogens compared to waterways in healthy native forest ecosystems. When accompanied with the absence of riparian vegetation along stream and wetland margins the result is increased levels of these contaminants reaching our natural waterways. As a result, most of New Zealand's streams are now undrinkable (because of high pathogen levels), many are unsuitable for swimming (pathogens), those beyond bush margins are often not suitable for many of our native fish and invertebrate species (because of high summer water temperatures and elevated sediment and nutrient levels), and a significant percentage are unsuitable even as a source of water for livestock. Restored and well-managed riparian areas can serve as effective buffers between natural waterways and areas of human occupation and production (industry and agriculture). Sediment and nutrients enter waterways by two routes - by overland flow or through ground water. These two pathways require different strategies to control nutrients.

The installation of stock-proof fencing and the re-establishment of a buffer zone of riparian vegetation can effectively filter out many of the contaminants generated by agriculture and forestry, especially those that are carried to the waterways in surface runoff: sediment; phosphorus; pathogens; and particulate nitrogen.

Expectations and the effectiveness of riperian buffer vegetation have been reviewed (e.g., Parkyn 2004; Parkyn et al. 2003).

Unfenced streams can become heavily contaminated with sediment and phosphorus generated by stock crossings, unstable stream banks, and surface runoff.

SEDIMENT

Cause and effects

Suspended sediment levels in streams draining pasture are likely to be between two and five times higher than in streams draining native forests (Quinn et al. 1997). This is partly due to the increased volume and velocity of surface water runoff that occurs on land that has been cleared of forest, but predominantly as a result of farm livestock, grazing and soil management practices.

The main sources of sediment reaching streams are from slips and slumps (on steeper land), earth exposed by treading and pugging by livestock, roads and tracks, cultivation and stream bank erosion. The amount of sediment generated is likely to be greatest on steep slopes, saturated soils and erosion-prone soil types; where stocking rates are high or pasture is over grazed; where livestock have access to stream margins; where cultivated soil is left bare for long periods; and where farm tracks and roads are poorly drained and maintained.

High levels of sediment in streams reduces the drinkability of the water and appeal of the water for recreation, but perhaps the greatest impact of sediment is on aquatic life. High suspended sediment levels clog the food filtering mechanisms of stream invertebrates, cover the preferred stony bottom habitat of indigenous plants and animals, reduce visibility and therefore prey catching ability, and often carry nutrients such as phosphorus that can further alter the habitat.

Erosion of unfenced stream banks exacerbated by stock trampling (above) contribute substantially to the subsequent increase of sediment loads in waterways (below).

Riparian planting and management to reduce sediment contamination of streams

Sediment is carried to waterways by water flowing across the surface of the ground. Any management techniques that can slow down the velocity of waterflow and filter out and hold the fine sediment particles carried in the surface water runoff will be successful at reducing the amount of sediment reaching waterways.

1. Grass/sedge filter strips

Grasses and sedges (native and exotic) are the best plant types for filtering out sediments. This is because they have a large volume of plant matter at ground level and a mass of fine roots that are most effective in nutrient uptake so are better able to intercept surface water flow than a tree or shrub. The more vegetation in the path of surface runoff the more the speed of the water is slowed and the greater the likelihood of sediment settling out. As well as trapping the sediment, grasses and sedges will generally grow over and through the sediment binding it in place.

Riparian trees and shrubs are not as effective as grasses, sedges and rushes at intercepting and removing sediment which contains phosphorus. Their stems are too coarse to trap the fine sediment transported in runoff. The woody debris and coarse organic matter typically found under mature native forest does function to filter out sediment but this material is usually absent from narrow and recently planted native tree and shrub riparian margins. Some close-spaced riparian native tree plantings, especially of small-leaved species such as kanuka (*Kunzea ericoides*) have been observed to increase sediment erosion because they create a dense canopy that prevents any ground cover plant species from establishing beneath them.

Best performing species

There are several native sedges and rushes that create excellent sediment filters when planted en masse. The fine leafed *Carex* sedges, including *Carex secta* and *Carex virgata*, and bulrushes (*Juncus* species) serve as a good "first line of defence" when planted at close spacings (0.5 to 1 metre apart) because of their dense growth form, their tolerance of periods of soil saturation and their ability to trap and grow through sizeable deposits of sediment. These species can be planted along wetland margins, in ephemeral drainage channels, in and around springs and seepage areas and along riparian fence lines. They are also very effective at stabilising stream banks against erosion especially in volatile streams that are prone to rapid flooding.

Harakeke or flax (*Phormium tenax*) and toetoe (*Cortaderia spp.)* can also be used on wetland margins and along riparian fencelines, although they should be kept out of drainage channels as their bulk can induce flooding. Exotic pasture grasses left to grow rank also serve as very effective sediment filters, especially at the base of steep slopes where the gradient levels out. They are not, however, tolerant of long periods of soil saturation. Over time exotic grass filters need to be maintained to prevent invasion of broadleaf and woody stem weeds which are less effective as filters.

Filter strip width and location

Where surface runoff descends down the slopes above the riparian zone diffusely (ie. not confined to channels or depressions) grass filter strips need to be established continuously along the fence line on the landward side of the riparian zone to be most effective at intercepting sediment. However, on long slopes runoff is usually concentrated in depressions, rills or channels by the time it reaches the riparian zone. When this is the case grass filters should be established in the depressions or channels where they will intercept the greatest amount of runoff.

There is no one optimum filter strip width or length, but the general rule is "the wider or longer, the better". The most effective filter strips are those that are:

- permanently fenced;
- positioned to intercept the greatest amount of surface runoff flow;
- as wide as possible for continuous strips along riparian margins, or as long as possible for filter vegetation planted in channels, so that all or most sediment is filtered out and trapped during normal rainfall events;
- densely covered with grass/sedge/rush vegetation to maximise runoff interception;
- lie on land with a very gentle slope; and
- not shaded by trees and shrubs.

The sediment filter strip should be widest at sites that receive runoff from steep, saturated, erosion prone, over-grazed land. On erosion prone sites the filter zone may have to be well over 10 metres wide to be effective. At sites where slopes drop steeply straight into stream channels (such as parts of the North Island East Coast area) filter strips cannot be expected to perform as effectively as on less steep land with streamside riparian flats. Even on favourable sites with wide filter strips the effectiveness of grass filter strips as a barrier for sediment will decline during periods of prolonged rain and accelerated soil erosion. It is a good idea to get out and observe the effectiveness of existing grass filters in the area during such heavy rain to gauge the performance of strips of varying widths.

Maintenance of grass filter strips

Grass and sedge species are not tolerant of shade and must be kept in full sun to retain their full vigour. They should not, therefore, be planted in amongst trees and shrubs along riparian margins, and over time naturally establishing tree and shrub species may need to be removed to maintain sufficient light levels to allow growth of ground cover vegetation.

2. Wetlands and seepage areas

Naturally occurring wet areas (permanent and seasonal) on relatively level ground at the base of gullies and valleys and where spring waters emerge are excellent sites to capture sediment (and nutrients - see below). Even relatively small wet areas can serve as a significant nutrient and sediment trap if restored and maintained.

To reactivate the sediment and nutrient extracting capacity of wetlands and swampy areas it is recommended that:

- drainage channels should be blocked off or in-filled to increase the water holding capacity and water retention time of the wetland;
- permanently wet areas should be permanently fenced from livestock;
- the wet parts of the wetland can be planted with bulrushes, native sedges and other native wetland grass, sedge and rush species to complement any existing bulrushes (which are tolerant of grazing) and replace exotic grasses; and
- the wetland margins can be planted with native sedges, flax and toetoe to create an additional filter strip.

Wetland margin tree species such as cabbage tree (*Cordyline australis*), ribbonwood (*Plagianthus regius*), kahikatea (*Dacrycarpus dacrydioides*), swamp maire (*Syzygium maire*) and pukatea (*Laurelia novae-zealandiae*) can be planted around the wetland margins. However, they will not assist greatly in the process of sediment retention and should be positioned so that they do NOT shade the wetland grasses, sedges and rushes.

This restored wetland is becoming dominated by native sedges (foreground) trapping sediment from surrounding farmland and the recently fenced riperian strip planted in native woody species (background).

3. Stream banks

Many streams that flow through pastureland have narrower channels and steeper banks than streams that flow through native bush. This is because the grasses growing on the stream banks trap and bind the greater sediment loads that are transported in surface runoff and in flood waters arising from farm land.

If native trees and shrubs are planted to provide shade to the stream channel and enhance the habitat for aquatic life, the grasses growing on the stream banks are likely to lose vigour and eventually die out. This will release the sediment held on the stream bank, increasing the amount of sediment entering the waterway for a period. Eventually (over many years or decades) the stream channel will widen and sediment levels will drop away. So if the management priority for an existing agricultural stream is to keep in-stream sediment levels to a minimum, then planting shade trees will need to be avoided.

PHOSPHORUS

Cause and effects

The amount of phosphorus lost (exported) from grazed pastureland can typically be 10 to 15 times greater than that lost from native forest systems (Ministry for the Environment 2000). The amount of phosphorus actually reaching our waterways is closely related to the levels of sediment contamination. This is because phosphates most commonly attach onto clay and other soil particles and both are transported across the soil surface by water runoff. Consequently, phosphorus contamination in waterways is greatest where soil erosion and surface runoff are most likely - on steep, erosion prone and saturated soils.

The principal sources of elevated phosphorus levels on farms are from phosphatic fertilisers and dung from livestock.

While phosphorus does not occur in our waterways at concentrations that are toxic to humans or livestock, high phosphorus levels can lead to excessive algal growth
and nuisance plant growth in streams and lakes.

This retired area has been planted in native trees and shrubs and all of the rank grass sprayed with herbicide. This riparian zone would function much more effectively as a barrier to sediment and phosphorus if the grass between the plants was not sprayed out. The steep stream banks can be expected to collapse over time because of the lack of stream edge grasses and sedges to hold the sediment in place.

Riparian planting and management to reduce phosphorus contamination of streams

The reduction of phosphorus contamination of our waterways can be achieved by the establishment of grass, sedge and rush filter strips and the restoration of wetlands and seeps in the same way as for sediment management (refer previous section).

The phosphorus contained in the sediment trapped by filter vegetation provides a ready source of nutrient to sustain the filter vegetation.

The impact of high phosphorus levels in stream water can be reduced by providing shade over the stream channel. Reduced light levels will reduce the amount of weed and algae growth even when phosphorus concentrations remain high.

NITROGEN

Cause and effects

The historic use of clover and the increasing use of nitrogen fertilisers have enhanced pasture growth and improved farm productivity over the last 20 years. This increased use of nitrogen and the resulting increased production (and excretion of nitrogen-rich urine) has greatly increased the amount of nitrogen that is lost from the system and that eventually reaches our waterways. Recent studies in the Lake Taupo catchment and elsewhere (e.g., Ritherford et al. 2009) have shown that dairy pasture can yield as much as 14 times the amount of excess nitrogen compared to native forest (Environment Court 2008).

High levels of dissolved inorganic nitrogen, in the form of nitrate in our waterways can lead to profuse nuisance plant and algal growth, and sustained high levels of ammonia can be toxic to native fish. Very high nitrate levels can be toxic to livestock and humans.

Unlike phosphorus most nitrogen is lost from agricultural land by leaching down through the soil in the form of nitrate, rather than being transported across the land surface in runoff. The leached nitrate is carried in solution by water down until it intercepts groundwater and is then carried in groundwater until it emerges into streams, rivers, lakes and in springs. The principal sources of nitrogen are from nitrogen fertilisers and nitrogen fixation by clovers, but the excess nitrogen in groundwater derives almost exclusively from livestock urine patches.

Nitrogen contamination of streams is likely to be greatest where:

- intensive farming practices are used;
- high levels of nitrogen, well in excess of plant needs, are present in the soil;
- livestock have free access to streams;
- soils are porous; and
- rainfall is high or irrigation water is being applied.

Cattle with direct access to streams are a major source of nitrogen and faecal pathogens in our waterways in addition to increased sediment loads from trampling over stream banks.

Riparian planting and management to reduce nitrogen contamination of streams

Nitrogen contamination of waterways is considerably more difficult to reduce than phosphorus because most nitrogen is immediately leached down into the soil at the point of contact. Consequently, much of the research effort to reduce nitrogen reaching our streams, rivers and lakes is being focussed on finding ways of increasing the rate of utilisation of available nitrogen by plants and decreasing the propensity of that nitrogen to be leached.

Conventional planting of stream margins with trees, shrubs and grasses has little impact on the amount of nitrogen reaching waterways. A small percentage of nitrogen is carried in particulate and soluble form in surface runoff and it can be intercepted using grass filter strips. A small amount of nitrogen may be absorbed through the root systems of riparian trees and shrubs where groundwater is shallow. However, the majority of nitrogen contaminated groundwater bypasses stream margins.

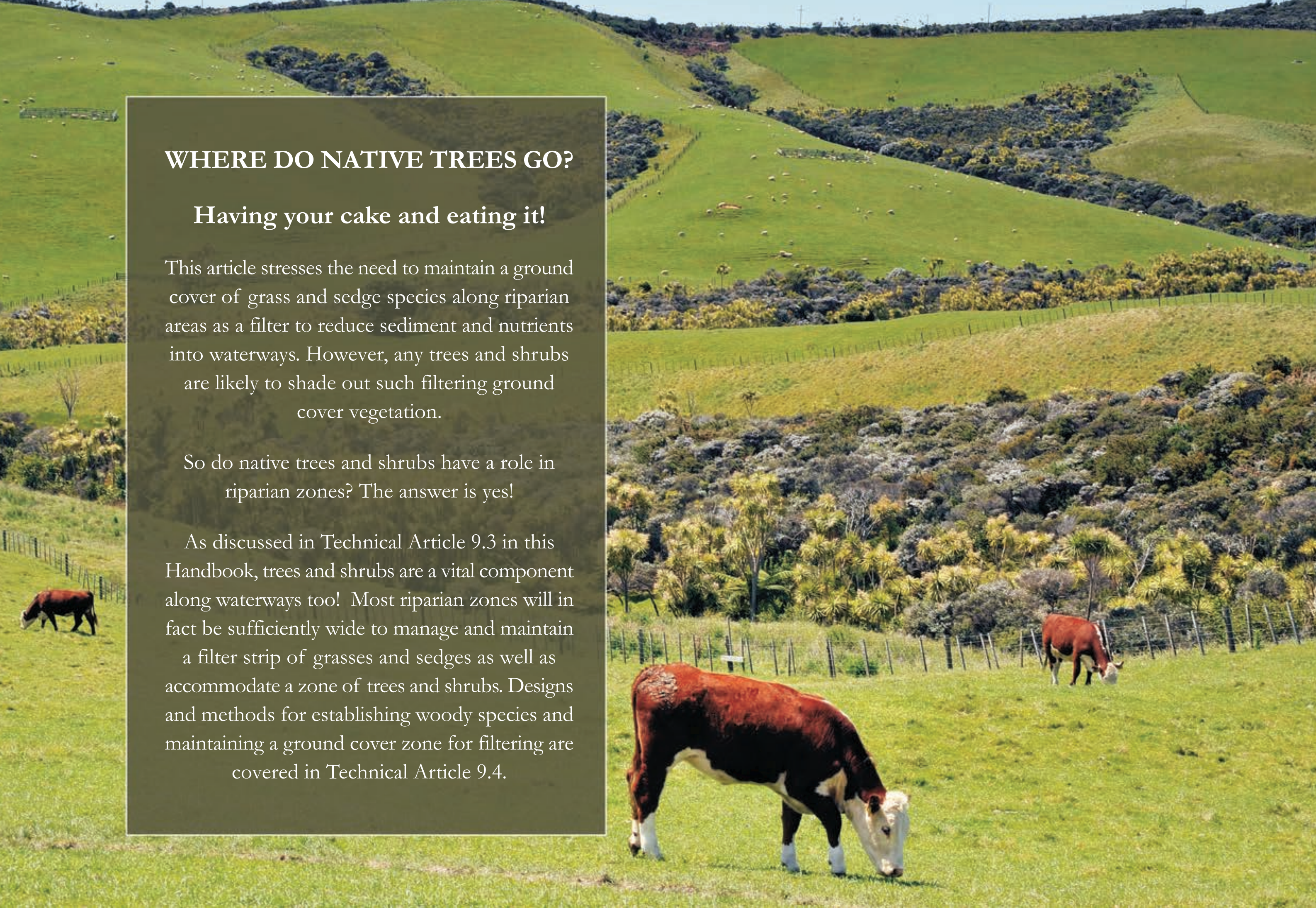
The most effective location for extracting nitrogen from groundwater using native plants is at springs and seepage zones at the base of hills. Spring water is re-emerging groundwater and every spring and its associated wetland is an opportunity to extract nitrogen before it flows into a major river or lake.

The nitrogen leached through soil and transported in solution by groundwater is largely in the form of nitrate (NO_3). Nitrate can be converted to gaseous nitrogen (N_2) by a process called denitrification when denitrifying bacteria, anaerobic conditions and a source of organic matter are present. When these conditions are present in a wetland soil and water retention times exceed minimum levels, more than 50% of the nitrate can be removed by the wetland (Nguyen et al. 1999).

Typically wetlands and seepage areas on farms have at some stage been drained. To increase the capacity for denitrification, all drainage channels need to be infilled to increase water retention times and spread the water out across the full wetland area. Wetlands that have been grazed will need to be fenced to exclude livestock and native wetland sedges and rushes planted to increase the organic matter content and water retention. Denitrifying bacteria occur naturally in healthy wetlands but require the existence of anaerobic conditions (resulting from pooled water and prolonged water retention) and abundant wetland vegetation to operate at levels that will remove significant amounts of nitrate from the system.

The greater the physical length of a wetland system the greater the amount of nitrate that can be converted to atmospheric nitrogen. However, even relatively small wetland areas seem to be capable of removing at least some nitrogen, both by plant uptake and nitrification.

Spring generated wetlands can play an important role even in our most productive landscapes in the reduction of nitrogen, phosphorus and sediment loads to our waterways when fenced from livestock.



WHERE DO NATIVE TREES GO?

Having your cake and eating it!

This article stresses the need to maintain a ground cover of grass and sedge species along riparian areas as a filter to reduce sediment and nutrients into waterways. However, any trees and shrubs are likely to shade out such filtering ground cover vegetation.

So do native trees and shrubs have a role in riparian zones? The answer is yes!

As discussed in Technical Article 9.3 in this Handbook, trees and shrubs are a vital component along waterways too! Most riparian zones will in fact be sufficiently wide to manage and maintain a filter strip of grasses and sedges as well as accommodate a zone of trees and shrubs. Designs and methods for establishing woody species and maintaining a ground cover zone for filtering are covered in Technical Article 9.4.

FAECAL PATHOGENS

Cause and effects

Streams draining agricultural catchments can carry levels of faecal pathogens (bacteria, viruses and protozoa) that are over 20 times greater than those typically found in native forest streams (Smith et al. 1993). The presence of faecal pathogens in waterways provides an obvious and immediate threat to human health and, when contamination levels are high, to stock health. Most New Zealand streams are not suitable for drinking because of faecal contamination and many are not recommended for swimming for the same reason. *Campylobacter* is the most common source of food and waterborne illness in New Zealand (Ministry for the Environment 2000). Other harmful organisms that can be found in contaminated waterways include *Salmonella, Giardia,* and *Cryptosporidium.*

Faecal contamination occurs when faecal material is deposited directly by farm livestock into unfenced waterways, where dung is transported to streams in surface runoff, or where discharges from oxidation ponds flow into waterways.

Riparian planting and management to reduce faecal contamination of streams

Fencing to permanently exclude livestock from waterways is the single most effective way of reducing faecal contamination of fresh water.

The establishment of grass filter strips and the restoration of sedge/rush wetlands that intercept surface runoff are effective methods for reducing the volume of faecal material reaching streams in runoff. The grasses work in the same way as they do for sediment and phosphorus: they slow the velocity of surface water runoff so that the dung particles are able to settle out (see previous sections for details). Trapped faecal organisms are killed by dehydration and exposure to sunlight so the longer the grass strip can trap them the greater the mortality. To retain the vigour of the grasses, sedges and rushes and to induce maximum mortality of pathogens, shading should be avoided.

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Author: Roger MacGibbon, Natural Logic Ltd

Contact: Tãne's Tree Trust
Website: www.tanestrees.org.nz

Tãne's Tree Trust — Native Trees for the Future

Tãne's Tree Trust promotes the successful planting and sustainable management of New Zealand native trees and shrubs for multiple uses.

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