Managing Waterways on Farms

A guide to sustainable water and riparian management in rural New Zealand

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Preface

Riparian areas are those which adjoin water bodies, such as streams, rivers and lakes. Riparian vegetation shades and feeds the stream, protects its banks, and filters water passing through it. As the eminent limnologist HBN Hynes once remarked, "in every respect the valley rules the stream". And hence, how we manage our land will affect the quality and the values associated with the stream.

In recent years there has been a growing awareness that appropriate riparian management is vital to maintaining the quality and biodiversity of our water bodies. Streams, rivers and lakes not benefiting from such management exhibit degraded biodiversity and water quality unsuitable for many desired uses such as swimming, water supplies and, in some cases, even for stock watering. There has been a great deal of research and there are many good examples of riparian management. While our focus should always be on the way we manage the land we directly crop, many of the inevitable impacts of farming and forestry can be buffered by effective riparian management.

This document is primarily a reference manual for those who advise farmers and foresters in how they manage their land. I hope that it will also enable landusers who wish to make a change to plan their own riparian management regimes. An extensive bibliography with references and further reading leads the reader to information that cannot be condensed into a document of this size.

Farming and forestry remain the lifeblood of New Zealand and they have profound effects on our land and water resources. I commend you to read this manual and consider how your land is being managed.

Denise F Church
Chief Executive
Ministry for the Environment
June 2000

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1 Introduction

Water is an essential element for all life and is valued by all cultures. It is of special significance to Maori who believe that all elements of the environment, including water, possess a life force or mauri. A waterway with an intact, healthy mauri can be identified by the healthy ecosystems that it supports. Our native plant and animal communities in streams, rivers and lakes need clean unpolluted water. While humans require clean water for domestic and industrial supplies and for many recreational activities. The farming community relies on water for stock and irrigation. Yet rural development and urbanisation have increased the amount of contaminants reaching our waterways and have degraded associated habitats (Smith et al, 1993).

Farmers[1] are becoming increasingly aware of the impacts that their land management practices are having and how these impacts can affect others in the wider community. Many are changing the way they manage their land to reduce these impacts. But others are yet to make the positive changes needed, so many of our streams, rivers and lakes continue to degrade. This problem is such that that some lowland streams are not only unsuitable for us to drink or swim in, they are unsafe for livestock to drink.

There are many reasons why some farmers have not yet acted to improve the management of land next to their waterways. Retirement fencing and tree planting are seen by many landowners and advisers as expensive with little apparent productive benefit. In times when there is generally decreasing financial support from local and central government for erosion control and riparian retirement and farm profitability is falling, capital improvements of this kind are less likely to occur. It is important, therefore, that such management practices are cost-effective.

Perhaps the greatest reason for inaction is a lack of understanding about the impact of farming activities, such as the source of farm-generated contaminants and how they enter streams, rivers and drains. Without that understanding, landowners and technicians are neither motivated nor equipped to apply appropriate management techniques that are necessary to make a difference. Where the knowledge does exist, extraordinary progress has been made by individual landowners, often at little or no net cost to the farming operation. Increasingly, we see that more sustainable land and water management can contribute to, rather than contradict, increased farm profitability.

This publication is aimed at those who provide advice to farmers about how they manage their land, and to those farmers who wish to enhance their properties and reduce the impacts of their farming operations. We hope it will be used by field officers, consultants, farmers, landcare group members, and hapu and whanau who have practical involvement "on the ground". This publication seeks to provide some background information about the sources, causes and processes involved with the deterioration of streams in farmed catchments and the consequences of that deterioration. Readers can thus better understand the problems and, as a consequence, be better equipped to manage the problems.

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1 We have adopted a broad interpretation of "farmers" as including all those who farm the land, including pastoral farmers, arable croppers, foresters, market gardeners, and fruit growers. Similarly, "farms" include dairy farms, wheat fields, commercial forests, etc.

The 16 case studies cover farms from Northland to Southland, dry and wet, cattle, sheep, and deer, orcharding and market gardening, community initiatives and individual achievements. Good ideas and good practices are highlighted, the costs and benefits of actions are analysed, and future management options are proposed.

1.1 Understanding riparian areas

The extent of riparian land is most clearly defined in natural unmodified areas by the existence of **riparian vegetation**, a distinct assemblage of plants uniquely suited to the zone between aquatic and terrestrial ecosystems. The plant and animal communities naturally occurring in riparian margins to a large extent owe their existence to the conditions created by the waterway; equally, the health and condition of the waterway, and its water and its inhabitants, can be significantly affected by the plants and the animals occurring along the riparian margin.

Gregory et al (1991) define riparian zones as "three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems". This definition emphasises the importance of the riparian area as a link and a buffer between the terrestrial and the aquatic zones, and its role in this regard is an important component of effective riparian management.

This link is important to Maori, who believe that when links between the various components of the catchment are broken, damage spreads through a catchment to the detriment of all those depending on the resource. In many parts of the world, including New Zealand, this intimate relationship between land and water has been interrupted and degraded.

For practical management, the best definition of the riparian zone is:

> *Any land that adjoins or directly influences, or is influenced by, a body of water or an area where water accumulates periodically. It includes:*
>
> - *the land immediately alongside streams and rivers, including the riverbank itself*
> - *areas immediately surrounding lakes*
> - *river floodplains and associated wetlands and seepage zones which interact with the river permanently or in times of flood*
> - *estuarine margins especially where streams and rivers exit.*[2]

[2] Modified from "Managing Riparian Land", Riparian Management 1, LWRRDC, Australia.

1.2 Why manage riparian areas?

Many of the reasons for riparian management revolve around the desire to improve aspects of water quality. Land that has a significant influence on waterways can extend well beyond the narrow strip along each riverbank. While the condition of the riparian zone will have a strong impact on the quality of water in a waterway, it is important to understand that some of the more effective water quality and stream health management practices may require good management practices beyond riparian zone.

Effective stream management can and should include the management of land in the wider catchment, the management of groundwater, and the management of the waterway itself including the water and associated instream values. This equates to catchment management; the management of all of the sources of water to a waterway.

An intact, healthy mauri depends on the status of all components of the catchment. Consequently, a sound understanding of how water and land interact across the catchment, and the riparian zone is essential to sound management.

1.3 What is a healthy waterway?

1.3.1 The way it used to be

Before human settlement, the water of most of New Zealand’s streams, rivers, wetlands and lakes passed for a substantial part of its journey through forest before entering the sea. The riparian zones alongside those waterways were typically covered by luxuriant and diverse riparian forest that extended from the stream edge across the plains and hills. On higher or drier land, where forests did not exist, the riparian zones and stream margins were characterised by weeping tussocks and sedges and seepage zones occupied by flax, sedge and cabbage trees.

Most small streams were heavily shaded (over 90 percent shade), and the plant and animal life within the stream was specifically adapted to high shade, low temperature waters, and an array of organic matter (leaves and wood) delivered to the stream from the surrounding vegetation. Larger rivers were less well-shaded as channel width opened a gap in the forest canopy, but they remained relatively cool, because of shading in their headwaters.

Unencumbered by high sediment input, the stream channels in forested catchments meandered more than pasture streams do today, and there were low levels of algae and aquatic plant growths because of shading and low nutrients input from the land. The waters were clear, cool and almost free of pathogens. Forested upper catchments intercepted a significant portion of the rain, so that floods were less frequent than they are today. Due to substantial vegetation cover, there was considerably less soil and streambank erosion.

Riparian zones were favoured habitat and dispersal areas for birds, insects, amphibians and other animals because of the easy topography and abundance of food and water. Plant diversity was readily maintained, thanks to the seeds brought by animals (especially birds), winds and waters.

Photograph 1: In pre-human times the majority of New Zealand's lowland streams were heavily shaded by thick riparian vegetation. They were cool, meandering, stony bottomed and contained abundant invertebrate and fish life.

1.3.2 Riparian and stream fauna

Our waterways and riparian zones are used by a wide array of native species including over 450 species of insects, giant snails and worms, freshwater fish, frogs and 88 terrestrial bird species. A large percentage are not found anywhere else in the world, and many are threatened.

1.3.3 Riparian vegetation

Over much of New Zealand native riparian vegetation has been cleared and replaced with agricultural pastures and exotic forestry or developed for human occupation and recreation. Consequently, the buffering and habitat functions of those riparian areas have, in many situations, been lost or seriously compromised.

The composition and extent of vegetation influences how well the riparian area functions. Consequently the condition of the riparian zone greatly influences the state of the waterway. For Maori, the riparian vegetation within a catchment was also important in determining the special and unique characteristics of a catchment, which in turn influenced the abundance and diversity of mahinga kai species that were present. Where the extent and type of vegetation has changed it is likely that the composition of mahinga kai species and their abundance will have changed.

1.3.4 Riparian zone function

Healthy, functional riparian areas (including riparian vegetation) provide three important benefits:

- They reduce or buffer the impact of land-based processes (natural and human-induced) on waterways by:
  - reducing erosion by slowing down the speed of overland water flow before it reaches the stream
  - filtering inputs of nutrients, soil, microbes and agricultural chemicals in overland flow
  - denitrifying groundwater
  - utilising some nutrients for plant growth before they enter the stream.
- They reduce or buffer the impact of water-borne processes (natural and human-induced) on adjacent land by:
  - protecting banks from erosion
  - buffering channels from localised changes in morphology
  - buffering the impacts of floods.
- They promote and sustain instream plants and animals by:
  - reducing fine sediment levels
  - maintaining water clarity
  - providing instream food supplies and habitat
  - preventing nuisance plant growths
  - maintaining lower summer maximum temperatures
  - reducing light levels
  - maintaining natural food webs.

In a typical farm waterway with little or no riparian vegetation, or subsurface drainage (eg, Mole and tile or Novaflow), the ability of the riparian vegetation to filter contaminants, provide shading, bank stability and organic inputs is greatly reduced.

However, well-vegetated riparian areas can also have negative impacts. They can:

- be habitat and dispersal corridors for animal pests, including the possum, ferret, stoat, feral cat, rat and mouse
- provide habitat for exotic weed species, but usually only when the riparian area has been poorly revegetated or managed
- harbour residual populations of problem insects.

Figure 1 compares a natural stream with intact riparian area and a typical farm drain.

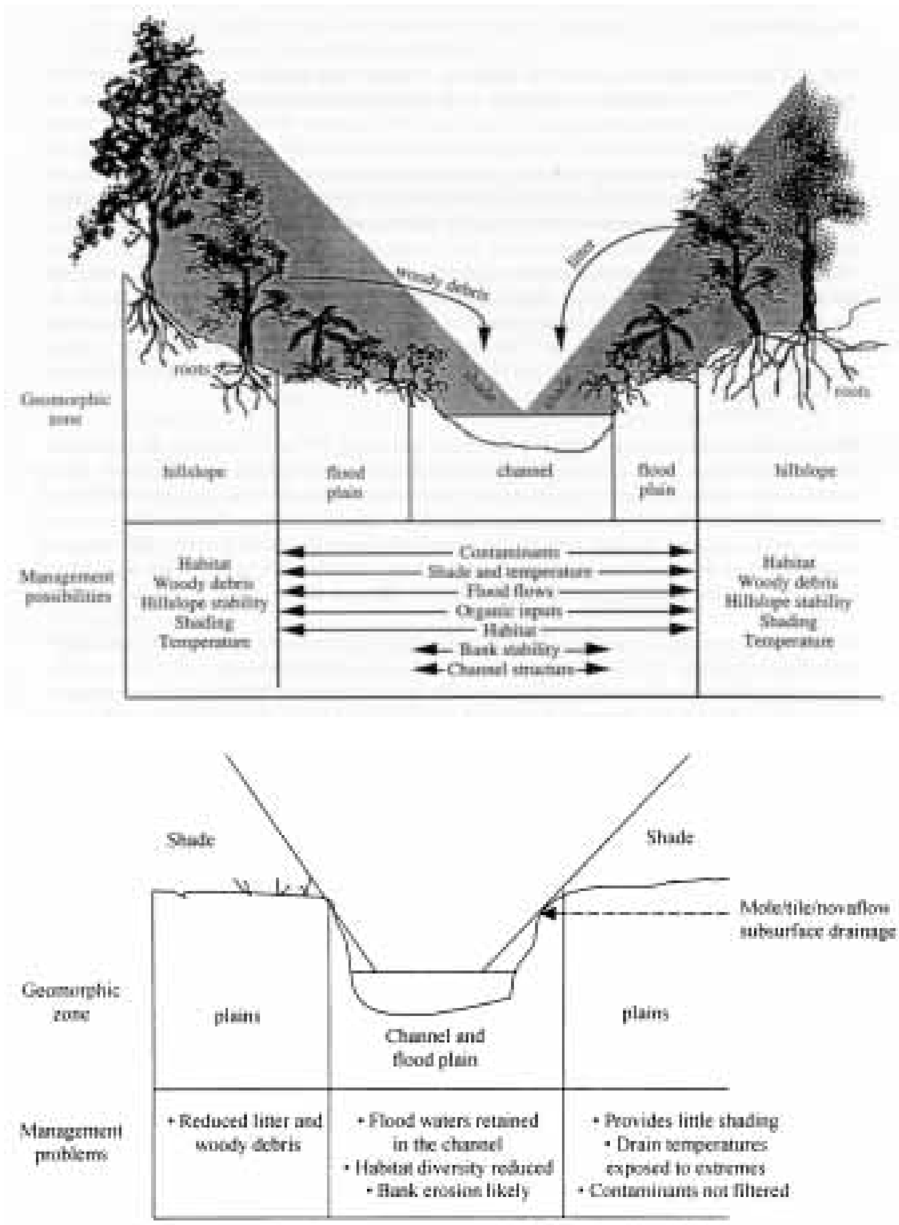

Figure 1: Conceptual diagram comparing the geomorphic zones and management issues of a typical drain and a natural stream *(modified from Collier et al., 1995)*

2 The Maori Perspective: Customary and Traditional Freshwater and Riparian Values

2.1 Overview

The Maori perspective of land and water is, in some ways, quite distinct from that of New Zealanders of European descent, although increasingly the more holistic Maori view is being embraced by all New Zealanders. The spiritual significance of place and the interconnectedness of people and land (and water) are increasingly strong influences on our perception of place.

The Maori view of the world does not separate spiritual aspects from the physical practices of resource management. All elements of the natural environment (including people) possess a mauri or life force and all forms of life are related. Maori see themselves as part of the environment, belonging to it and complementing other entities. The interconnectedness of all things means that the welfare of any part of the environment will directly impact on the welfare of the people. Tamper with or destroy any part, and you weaken the whole. The primary objective of Maori environmental management is to maintain the integrity of the connective life force. Resource use and allocation decisions are measured against this objective.

2.2 Maori and freshwater resources

Maori have strong cultural, traditional and historic links with wetlands and inland waterways, including lakes, rivers, streams and springs. The lives of Maori were intimately connected to the quantity and quality of the freshwater that was available to them. These resources provide habitat and spawning grounds for indigenous plants, bird and fish life, building and weaving materials such as raupo and flax, and medicines and dyes used for seasoning timber and restoring precious artefacts. They are also a traditional source of foods such as tuna (eel), whitebait and watercress.

Modifications to waterways, riparian areas and the wider catchment have altered the relationship of Maori with these resources. The protection of the integrity of valued freshwater resources remains an important aspect of the responsibilities of Maori who are identified as the tiaki (guardians). Values (both tangible and intangible) that are assigned to specific water bodies include:

- the role of waterways in tribal creation stories
- the proximity of important waahi tapu, waahi taonga, settlement or other historical sites in specific waterways or found in the riparian areas adjacent to the waterways
- the use of waterways as access routes or transport courses
- the value of waterways and riparian areas as sources of mahinga kai and other cultural materials
- the continued capacity for future generations to access, use and protect the resources of the waterways and riparian areas.

Maori conceive that each waterway carries its own mauri, guarded by separate spiritual guardians and tribal caretakers and having its own status or mana. A water body with a healthy mauri will sustain healthy ecosystems, support cultural uses and mahinga kai (food sources), and be a source of pride and identity to the people. While the mauri ensures that that all flora and fauna supported by the water have continued life, the mauri is defenceless against and at risk of desecration from actions that are not part of the natural realm, such as removal of native riparian vegetation, contamination or drainage. Hence the interest of Maori in the issues being discussed in this document.

It is possible to identify the specific activities that are of concern to Maori. In addition to the issues of vegetation clearance, modification of water flow and contamination of freshwater resources, the mixing of water is of particular concern. The mixing of waters by unnatural means, the mixing of waters from different sources with separate mauri, or discharges of “used” waters or wastes to living waters that supply food are contrary to the Maori conception of a healthy environment. These activities are considered to degrade the mauri of the waters and may also offend the mana of different iwi who hold traditional rights and responsibilities with respect to the different waterways. Diffuse and point-source contaminants that enter stream water from farmland (and from urban land) therefore contribute significantly to the degradation of the mauri of streams running through agricultural land. Waters diverted (for irrigation, for example) from one river to another is also an activity that is not favoured.

2.3 Waterway management and restoration

Consistent with many of the principles outlined in parts of this report, restoring the ecological and spiritual integrity of degraded waterways is a very significant principle in modern Maori resource management. Restorative action, including the replenishing of water quantity, improving water quality, and habitat restoration, are seen as priorities, particularly with respect to resources of high ecological or cultural value. Maori have developed a complex system of practices, customs and rules for the management of water resources. Included amongst these are kaitiakitanga, wai tapu and wai taonga, and rahui.

Kaitiakitanga is the responsibility of specific appointed iwi representatives to carry out particular functions, to keep and guard iwi interests and taonga (treasures or prized possessions). Tiaki are responsible for this preservation and guardianship. The obligations of tiaki include enforcement of the practices of tikanga, or those customary practices established to nourish and control the relationship between people and the natural world. Tiaki are responsible for ensuring that taonga are passed on in as good as, if not enhanced, condition to future generations. For this reason, tiaki are likely to have an interest in the development and implementation of restorative programmes.

Wai tapu and **wai taonga:** Water may be considered to be tapu, or sacred, because of its properties in relation to other water, tapu places or objects, and its close association with the gods. In other instances, water bodies will have special taonga value because of special uses that are not restricted by the prohibitions of tapu. The tapu or taonga status of a waterway is dependent on the preservation of their purity and the avoidance of unprotected contact with humans. Maori are likely to seek absolute protection of waterways with tapu status, and to protect the quality and quantity of waters whose uses are of special taonga value.

Rahui is an act of prohibition, often temporary, imposed to conserve or replenish a resource. When a rahui is placed upon a river, lake, forest or harbour, people are banned from using specific resources within a prohibited area.

- When management options are being considered for a waterway and its associated riparian zone, it is important to be aware that iwi patterns of usage vary throughout a catchment.
- Iwi have an interest in the whole water body from its source to the sea.
- Many mahinga kai species are migratory; therefore, the whole catchment needs to be considered, not just the sites where Maori gather mahinga kai.
- Iwi harvest different species in different locations and at different times of the year.

2.4 Values to consider

It is important for landowners, resource managers and others who are promoting restoration or enhancement programmes to have an understanding of the values that iwi are likely to want included in a waterway management plan or a specific restoration plan.

2.4.1 Mauri

Human activities (including many of the rural activities described here) have the potential to degrade or extinguish the mauri of the water body and as a result may offend the mana of those who hold traditional rights and responsibilities with respect to that water body. The mauri of the river is degraded if it no longer has the capacity to support traditional uses and values.

One of the principal indicators by which Maori will assess the mauri of a water body is its productivity and the food and other materials sourced from it. As noted earlier iwi, hapu and whanau have specific examples of rivers, streams, lakes and wetlands where the mauri is degraded. Further, if consulted, they can identify the activities that have adversely affected the mauri and help formulate a plan of action for restoring the mauri. In particular, waterway management for mauri should consider:

- water quality: contamination of a water body will diminish its mauri
- water quantity: mauri can be diminished by reduced and altered flows. A river cannot be a healthy river without sufficient amounts of flowing water
- flow variability: to protect the natural "moods" of the river. This should consider the daily, seasonal and yearly variations, low flows and flood flows, and minimum flow requirements
- flow variability to protect the normal river processes, such as sediment movement and river mouth closure
- mixing of waters from different rivers: mauri will be diminished where this occurs
- fitness for cultural usage
- life-supporting capacity and ecosystem robustness
- productive capacity.

It is essential that iwi are given the opportunity to identify those water bodies or reaches that need remedial or restorative action to maintain or replenish mauri. Only the iwi, as tiaki, can confirm if a particular river flow is sufficient to meet the metaphysical aspects of mauri. Because the mauri of each ecosystem will differ, the means by which the health and well-being of these ecosystems is to be restored, maintained and protected is also likely to differ. It may be advantageous for landowners, resource managers and scientists, together with Maori, to discuss and agree a plan of action.

2.4.2 Mahinga kai

Mahinga kai was and remains one of the cornerstones of Maori culture. In many instances the survival of iwi was dependent upon their knowledge of mahinga kai and their ability to gather resources. Healthy water bodies are valued because they continue to:

- be a direct source of mahinga kai
- provide ecosystem support for mahinga kai species
- support other significant mahinga kai environments such as forests, riparian habitats and coastal environs.

Maori are likely to accord special value to a water body (including its associated riparian areas) that:

- provides significant habitats for important food species and materials such as eels, watercress, flax, among others
- affords breeding and migratory environments for those species and the species they feed on in wetlands and lagoons
- has long-standing use histories for whanau, hapu and iwi
- deserves protection because it safeguards critical habitats, protects robust ecosystems, or represents degraded mahinga kai environments that are in need of restoration.

There are many examples throughout the country, however, where inappropriate riparian and water management has impacted on mahinga kai. Observable effects include:

- alterations to the abundance and distribution of species
- disturbances to the breeding cycles and patterns
- loss of access to water bodies
- the deterioration, reduction and removal of habitat.

Maori continue to voice their concern at the degraded state of many of the freshwater resources on which their survival and their cultural identity depended. The decline in both water quantity and water quality has impacted on the cultural values and traditional uses of catchments, in particular the mahinga kai resources.

Ensuring the health and well-being of freshwater resources is seen by Maori as a prerequisite for ensuring the continued health and well-being of mahinga kai resources and ultimately the improved health of Maori.

For Maori, participation in mahinga kai gathering is an important expression of cultural identity. Continuation of traditional practices is an important means of passing values down to children and grandchildren, ensuring their survival through the generations.

Where the maintenance and enhancement of mahinga kai is a management objective, iwi must be given the opportunity to identify those waterways or reaches of the water that are significant.

2.4.3 Waahi tapu

Waahi tapu are any places or features of such significance to whanau, hapu or iwi that protection is the objective.

Waterway management should give consideration to:

- identification of any waahi tapu that may be affected by changes in flow regime or changes in the wider catchment
- development of controls necessary to ensure waahi tapu are protected.

2.5 Integrated catchment management

Water has many different uses and different levels of significance for many parts of society. Effective water and riparian management requires that all of the diverse interests, including those of Maori, are recognised and given consideration before a restoration strategy is developed. This is especially so when managing water, because the effects of an action may be more significant downstream than at the site where the action is undertaken.

The Maori concept of the interconnectedness of land, water and people is very much consistent with the modern understanding of sustainability. Maori prefer a holistic and integrated approach to resource management because they understand and acknowledge that a river is not a collection of segments that can be managed as separate units.

The catchment approach to water and riparian management recognises that all activities in the catchment can and do have an effect on water. The catchment model also emphasises the importance of having the willing cooperation of all those residing, or with interests, in the catchment if sustainable management of our water resources is to occur.

2.6 Participation of Maori

While it is recommended that resource managers and landowners consult with Maori, they need to recognise that there may be aspects of Maori's relationship with a catchment that will remain confidential. However, this should not prevent resource managers from encouraging the active participation of tiaki. Participation represents explicit recognition by landowners and resource managers that it is the responsibility of tiaki to protect a waterway.

Therefore, it is recommended that:

- tiaki be given the opportunity to participate in the development of water management plans, riparian management plans and restoration and enhancement programmes
- tiaki be actively involved in determining acceptable management regimes, especially the setting of minimum flows and water quality standards.

The active participation of Maori recognises that tiaki know the waterways for which they have traditional responsibility. They know why and how the rivers were valued and used by Maori. More importantly from a resource manager's and landowner's point of view, Maori can describe how the attributes of the waterway have changed over time.

3 Understanding the Issue

3.1 Impacts from agriculture on waterways

Sediment erosion and nutrient loss from land are natural processes. In natural, unmodified ecosystems stream communities rely on regular inputs of nutrients to sustain life. In healthy native bush, catastrophic slip erosion occurs in response to climatic events, as do periodic floods and droughts. However, many agricultural practices accelerate natural processes leading to consistently higher levels of sediment, nutrients and surges of bacterial material being present in stream waters in agricultural catchments.

While it is true that most of our streams, rivers and lakes are healthy by international standards, there is no doubt that the quality of water and waterways in all but the most unmodified parts of New Zealand has deteriorated significantly since the bush was cleared and converted to farmland. In many areas the deterioration continues, where land use and farm practices are changing and becoming more intensive, as well as in waterways, especially shallow lakes and estuaries, where sediments and nutrients tend to accumulate.

3.1.1 Deforestation

Perhaps the greatest single source of pressure on the health of New Zealand's water and waterways has been the clearance of hill and riparian forests to create farmland. Today, New Zealand has 10 times more grassland than it once had and only a quarter of its original forests. Often the riparian vegetation was the first to be cleared because it was easy to access and because soils were fertile and water was available.

Removal of forests greatly reduces canopy interception of rainfall and absorption capacity compared to grassland. Hence runoff increases, both in terms of volume and velocity, so where forest has been removed surface run-off and flood waters are increased.

Several catchment studies have shown that vegetation change significantly affects river flows. Catchments near Rotorua with different vegetation covers were compared by Dons (1987). In the forested catchment 70–75 percent of rainfall was absorbed by vegetation compared to only 55 percent in the pasture catchment. Figure 2 shows runoff from the forested catchments as being half to two-thirds that of the pasture catchment. Consequently, the pasture catchment had higher average stream flows and flood flows.

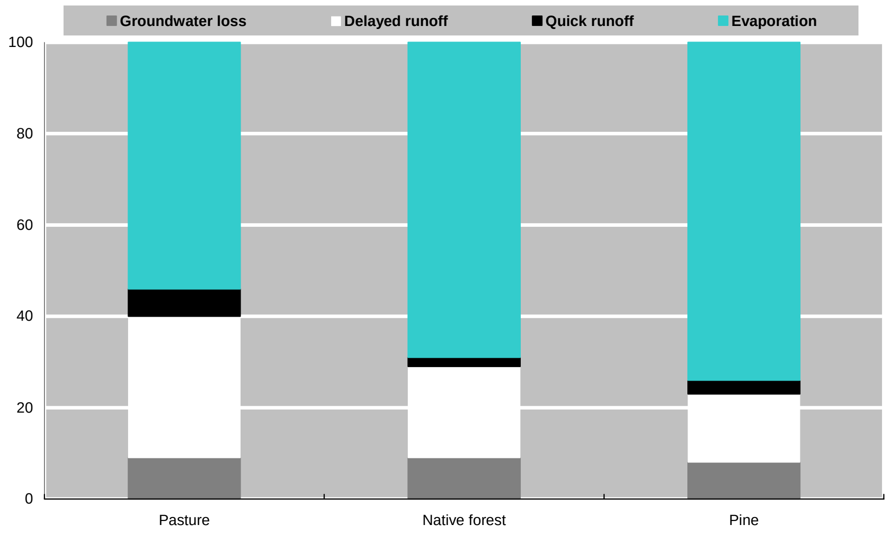

Figure 2: Patterns of water runoff from pasture, native forest and pine forest catchments at Purukohukohu, central North Island

Table 1 summarises the effects of the removal of native vegetation and its replacement with pasture. Many of the changes summarised in this table are discussed in later sections, and the variables outlined are revisited in later sections on management and restoration (Rutherford et al, 1997).

Table 1: Effect of replacing native vegetation by pasture on characteristics of hill-country streams at Whatawhata, near Hamilton *(Rutherford JC et al, 1997)*

Variable	Change	Mechanism	Effect
shade	reduced	reduced riparian vegetation	increased temperature, increased primary production, groundcover helps stabilise banks
runoff	increased	decreased interception, increased runoff rate	increased peak flows, increased catchment erosion and delivery
peak flow	increased	increased runoff	increased channel erosion
width	decreased	increased pasture encroachment, mass movement of soils	reduced streambed habitat
bank height	increased		increased water depth, increased bankside shading[a]
stock damage	increased	increased soil compaction, decreased groundcover, increased bank damage, voiding directly into stream	increased catchment erosion and delivery of sediment, increased nutrient supply
temperature	increased	increased solar radiation	loss of sensitive species, reduced dissolved oxygen saturation, increased respiration rates, increased plant growth rates
dissolved nitrogen	increased	increased catchment supply, reduced riparian removal, stock voiding into streams	increased potential primary production

Variable	Change	Mechanism	Effect
fine sediment	increased	increased catchment erosion and delivery, increased channel erosion, increased bank damage by stock	reduced boundary layer flows, loss of fish and invertebrate habitat, reduced clarity
clarity	reduced	increased fine sediment	degraded aesthetics, reduced visibility for animals
woody debris	reduced	reduced supply	reduced habitat diversity, reduced CPOM retention
coarse particulate organic matter	reduced	reduced litterfall, reduced retention	reduced food supply for shredders
primary production	increased	increased solar radiation, temperature and nutrient supply	increased food quantity for invertebrates, increased periphyton biomass[c]
periphyton biomass	increased[b]	increased primary production[c]	possible blooms, reduced boundary layer flows, reduced habitat diversity
invertebrates	altered	increased temperature and periphyton biomass, reduced habitat *quality* (increased fine sediment and reduced boundary layer flows, woody debris and CPOM retention), reduced habitat *quantity* (increased depth) of habitat	loss of sensitive species, increased snails, chironomids and oligochaetes, increased abundance and diversity

[a] but insufficient to compensate for the loss of shade vegetation
[b] biomass occasionally high but variable in space and time
[c] sometimes counteracted by increased grazing and sloughing

3.1.2 Riparian deforestation

The significance and functions of riparian vegetation are covered in Sections 2.2.3, 2.2.4 and 5. The main instream effects resulting from riparian deforestation have been:

- more rapid and extensive changes in stream bed morphology
- increased contamination of waterways
- increased magnitude and intensity of floods
- changes in seasonal flow patterns (especially summer low flows)
- loss of indigenous aquatic plant and animal habitat due to increased summer maximum water temperatures and reduced shade
- increased sediment build up and decreased water clarity; increased nutrient content; and loss of necessary plant and animal food sources
- increased instream nuisance aquatic plants
- changes in the abundance and diversity of mahinga kai species
- desecration of the mauri of the water body.

The main effects on riparian zones have been:

- increased loss of land and soil due to streambank erosion, increased volume and speed of runoff, and flooding
- loss of indigenous plant and animal habitat
- loss or reduction of wildlife dispersal corridors
- increased exotic weeds and animal pests
- loss of riparian wetlands that play a key role in nutrient removal.

3.1.3 Drainage of wetlands

Of the wetlands existing prior to human colonisation approximately 85 percent have been lost to farming, flood control, urban development and the creation of hydroelectricity reservoirs (MfE, 1997). The extent of wetland loss varies from region to region. Unmodified wetlands have been reduced to about 37 percent of their original area in Southland, about 25 percent in the Waikato, 2 percent on the Rangitikei Plains, and less than 1 percent in the Bay of Plenty. The once massive 25,840-hectare Gordonton peat bog in the Waikato, for example, now consists of three 13- to 60-hectare remnants.

Furthermore the loss of habitat and resultant fragmentation and isolation of wetlands has led to a decline in wetland animal species, and as a result many species are under threat.

Wetlands are highly valued by Maori because of the mahinga kai associated with them.

Wetlands are of considerable value because they act as sponges, absorbing and holding water and releasing it slowly over long periods. As well as slowing down the speed of water, the long holding period means sediments and faeces largely settle out, some nutrients are used by the wetland plants and dissolved nitrate nitrogen is converted to atmospheric gases (denitrification).

3.1.4 Construction of farm drains and drainage networks

The construction and maintenance of drains and drainage networks has been essential for the development and improvement of farm operations throughout New Zealand. Tens of thousands of kilometres of drains have been created throughout the country.

Effective drainage management is a vital component of successful and sustainable agriculture in most regions throughout New Zealand. As a consequence, many regional and district councils are responsible for managing and maintaining an extensive network of primary drains and waterways, while many individuals maintain smaller networks throughout their farms. These drains are either natural streams or wetlands that have been substantially modified, or channels constructed specifically for drainage purposes. However, it is important to remember that these drains are not isolated systems; they are linked both physically and biologically to the wider catchment. Upstream activities on surrounding land affect drains, which in turn affect downstream systems. In almost all cases drains eventually flow into natural steams that connect to larger aquatic systems (eg, rivers, wetlands, lakes and estuaries).

The three main functions of farm drains are to:

- lower water-tables
- increase the rate of surface runoff
- reduce the impacts of floods.

Regular maintenance is invariably required to maintain the efficiency of drains. Traditional drain maintenance practices have focused on hydraulic efficiency. These practices have encouraged the maintenance of bare, channelised, unobstructed waterways – free of weeds and marginal or riparian vegetation. However, the most widely used methods, mechanical cleaning and chemical spraying, can have serious impacts on water quality and waterway habitats. Furthermore, our understanding of the efficiency of these methods in maintaining flow while reducing contaminant run-off, and environmental degradation of downriver ecosystems is incomplete (Harding and Hudson, in preparation).

It is increasingly recognised that drains and artificial waterways play important environmental and ecological roles. In particular, drains act as conduits for a range of agricultural chemicals and other contaminants (especially faecal bacteria, pesticides, herbicides, nutrients and sediment) from farmland into larger aquatic systems.

Drains are also important habitat for a range of native and introduced plants and animals. In particular, habitat for key conservation (eg, giant and banded kokopu, Canterbury mudfish, and bitterns), commercial (eg, eels and whitebait) and recreational species (eg, mallard ducks), as well as sources of mahinga kai for iwi (eg, watercress, eels, whitebait and lamprey).

In most regions, draining of wetland and clearing of riparian zones along streams and rivers has resulted in the significant loss of fish and wildlife habitat. As a result, drains and smaller waterways may provide the only alternative habitat within a region for important native species eg, brown mudfish and banded rail. Furthermore, because these drains are linked to larger systems they may provide refuge for native fish from floods and from larger introduced predatory fish species.

Photograph 2: A typically maintained drain, with loss of most fish and wildlife habitat.

3.1.5 Fertiliser and stock

The introduction of livestock along with associated farm activities have intensified the problems created by the removal of forest cover, particularly in relation to water quality.

From the 1950s until the 1980s, sheep numbers increased substantially and with them the volume of fertiliser applied, especially superphosphate. Sheep numbers and fertiliser application decreased through the 1980s as economic returns from extensive pastoral agriculture declined, and in the last decade there has been a corresponding increase in more intensive forms of agriculture. Between 1981 and 1995, sheep numbers fell by 30 percent, from a subsidy-driven peak of about 70 million to just under 49 million.

Cattle numbers, however, have risen to an all-time high of 9.3 million, largely reflecting the 40 percent increase in dairy cattle from 2.9 million to 4.1 million. Dairying has now moved into areas not previously recognised as dairy farming areas (for example, Otago, Taumarunui, the western side of Lake Taupo and irrigated land in Canterbury) and has expanded in areas such as Northland, Southland and Taranaki, where dairy farming has existed in the past. There has also been an increase in beef cattle numbers on hill country, and in some areas dairy farming has extended onto rolling hill country.

With the expansion in dairying has come an increase in nitrogen fertiliser use in an attempt to boost grass growth. Nitrogen fertiliser sales have more than trebled from 1994-2000, with most dairy farmers applying 25–100 kg of nitrogen as fertiliser per hectare per year, and some up to 200 kg. With the increased levels of application comes an increased likelihood of some of it reaching streams and groundwater.

3.1.6 Impacts on stream communities

The replacement of native vegetation with introduced vegetation and the increase in agricultural contaminants nearby our streams have significantly altered the plant and communities in our waterways.

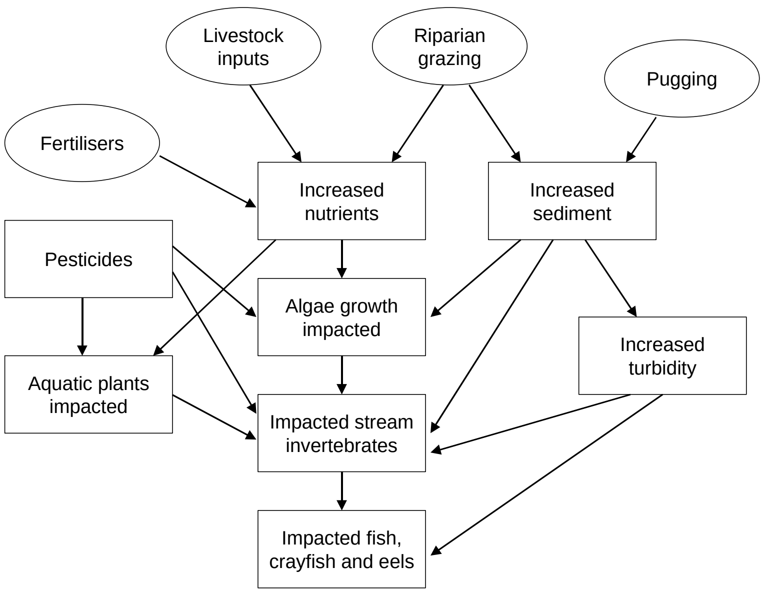

Figure 3: Summary of the effects of generalised agricultural activities on stream communities

Plants

Increased instream light levels and water temperature due to riparian vegetation clearance, and increased nutrient and sediment inputs from farmland have lead to a significant change in the aquatic plant life of agricultural streams compared to native forest streams. The low light levels of forested streams encourage both the development of thin algal films on stones and the growth of mosses and liverworts on stable substrates, which in turn can provide important habitats for many aquatic invertebrates in small streams.

Invertebrates

Nationwide, the main threats to freshwater invertebrates come from habitat degradation by catchment clearance, removal of riverbank vegetation, wetland drainage, diffuse and point source pollution, channel engineering works, mining, and the regulation of flow regimes. Excessive summer water temperatures, in conjunction with high sediment inputs, nutrients and low dissolved oxygen levels all contribute to the degraded invertebrate communities found in many agricultural streams.

The number of invertebrates in pasture streams is often greater than in forested sites. This is caused by organic enrichment and high temperatures, supporting high abundances of pollution tolerant species, especially as snails, chironomids (midge larvae) and oligochaetes (aquatic worms).

Many of our pasture streams exceed 20°C during the summer, and temperatures this high are known to affect the survival of many invertebrate species.

Fish

Several of our native fish species are under threat, particularly from introduced species, forest clearance, contaminants from pastoral farming and drainage works.

All of our fish species are predators, feeding on invertebrates and other fish species. They are able to adapt to varying degrees to changes in food supply associated with altered riparian vegetation. However, some of the larger galaxiid fish (eg, giant kokopu and banded kokopu) depend on native forest for good breeding habitats. Removal of natural riparian vegetation, may have had direct effects on the presence of these species.

Of concern to Maori is the impact of the removal of natural riparian vegetation and the increased input of contaminants on eels, this is particularly important as eels are still harvested commercially. The longevity of eels means that over its life it is likely to accumulate contaminants found in the waterway in which it lives. Although scientists confirm that eels are a valuable bio-indicator, the level of contamination in larger eels and the resultant impact on the health of people who eat the eels is unknown.

Riparian vegetation and wetland habitats, are also important for our three species of mudfish and their distribution appears to have been severely impacted by habitat loss associated with pastoral development of catchments.

About half of our native fish species are migratory and require access to or from the sea at some stage of their life. Dams, weirs and elevated culverts which create barriers to fish movement can prevent these species completing their lifecycle.

3.2 Contaminants from agriculture: impacts on water quality

The impact of agricultural contaminants on water quality can be divided into two categories:

- **Point source contaminants** discharged from specific sites such as dairy sheds, piggeries, septic tanks, leachates from silage pits and farm dumps: In most New Zealand rivers, pollution from point sources has declined noticeably over the past 10–20 years. This is partly because the total number of point sources has fallen, and partly because waste treatment processes have improved.

  In recent years, dairy farmers have been encouraged by regional councils to move to land-based methods of effluent disposal (eg, irrigation back onto pasture) as opposed to the standard oxidation pond system that has been used extensively since around 1975. This can reduce one point source of water pollution and replace it with another practice less likely to pollute waterways, although care also needs to be taken with land-based effluent disposal to avoid water contamination.

- **Diffuse or non-point source contaminants** arising generally from paddocks, forests and roads, and washing into streams as surface runoff: Although "traditional" sources of point-source pollution are declining, non-point source inputs from farm drains are still common. Drainage ditches frequently accumulate nutrients, sediment, herbicides and pesticides. Water from these drains frequently acts as "point-sources" of contaminants where they merge with natural waterways.

  Most diffuse pollution is caused by rainwater washing organic matter, sediment and nutrients from land surfaces into streams, rivers and lakes. Diffuse pollution also occurs when nutrients or other contaminants are leached through the soil into groundwater. The development of mole, tile and novaflow drainage has decreased the amount of surface water runoff from many farms, and increased subsurface flow enabling these contaminants to drain freely into drains and other waterways (Nguyen et al, 1998).

3.3 Nutrient enrichment

In natural, unmodified ecosystems inputs of nutrients and organic compounds (derived from vegetation decay) play a vital role in aquatic ecosystems. There are four main effects of enrichment (eutrophication):

- increased aquatic plant growth
- oxygen depletion
- pH variability
- changes in plant species quality and consequent food-chain effects.

The two nutrients most likely to cause excessive algal growths are nitrogen (particularly dissolved inorganic nitrogen), and phosphorus (especially as dissolved reactive phosphorus).

Excessive growths of algae and aquatic plants can cause problems in farm waterways by:

- changing the quantity and type of food available stream life
- altering the habitat for fish and invertebrates
- depleting the water's dissolved oxygen levels (through the decay of prolific growths)
- making them aesthetically unpleasant.

High nutrient levels will not always result in heavy growths of algae and other plants. Unsuitable substrate types, floods, low light levels (due to turbid waters or riparian shade), or high grazing rates (by instream invertebrates) will prevent the development of nuisance growths. However, unshaded, shallow lowland rivers with stony substrate are susceptible to algal proliferations. Aquatic plants are slower growing than algae and thus require stable flows and high nutrient concentrations over a longer period to reach nuisance, and are more likely in lowland rivers, lakes and estuaries with fine substrates.

3.3.1 Nitrogen

Agricultural non-point sources account for 75 percent of the total nitrogen loading to New Zealand surface waters (see Figure 4). The principal sources of high nitrogen levels on farmland are urine and dung from livestock, the application of nitrogenous fertiliser and nitrogen fixation by clovers.

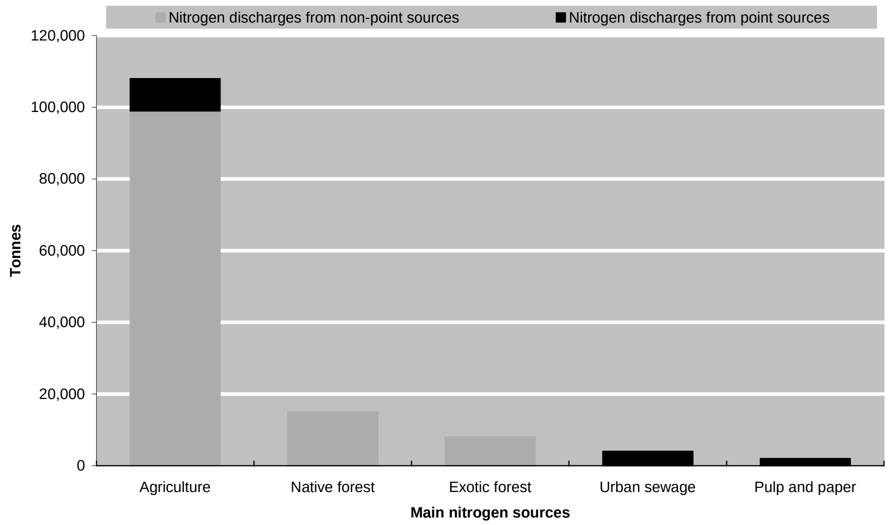

Figure 4: Estimated yearly nitrogen loadings to New Zealand surface waters *(MfE, 1997a)*

Nitrogen can be lost from pastures and cultivated land as surface runoff, or leached through the soil to groundwaters in the form of soluble nitrate nitrogen. On heavily grazed pasture, 100-200 kg of nitrogen per hectare per year could be lost from the soil, with most of it leached to groundwater (Ball, 1982). Nitrogen export from pasture hill catchments averages three to 10 times that of native forest (Cooper and Thomsen, 1988; Quinn et al, 1998). Figure 5 shows how nitrate loadings vary through the year, at different sites, in particular higher leaching rates are evident during the winter months.

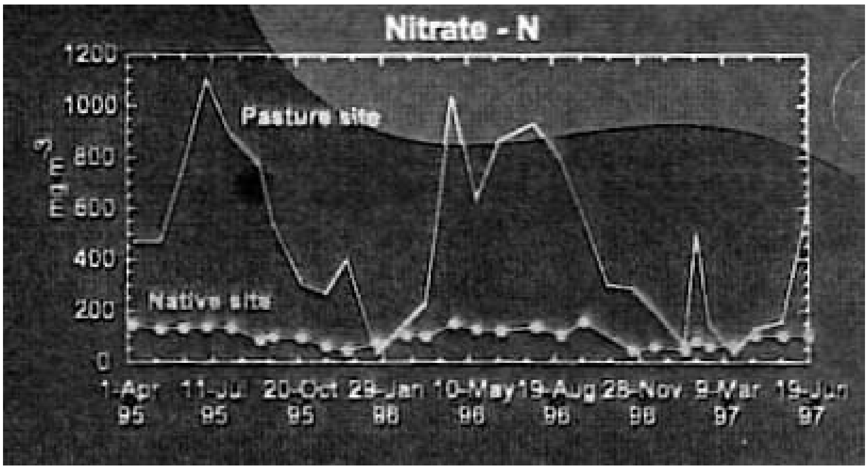

Figure 5: Hill-country farming effects, nitrate *(Quinn and Thorrold, 1998)*

The highest nitrogen fertiliser application rates, up to 400 kg/ha, have been recorded in market gardening areas, while comparatively low nitrogen is found in forested sites (Table 2). This is well in excess of the amount needed by plants to grow; the fertiliser not used by plants will be rapidly leached into the groundwater and end up in streams and rivers. Nitrogen fertiliser applications in excess of 200 kg/ha/year have been shown to significantly increase the nitrate contamination levels in groundwater.

Table 2: Nitrogen losses in runoff to streams in the Purukohukohu experimental catchments *(Cooper and Thomsen, 1988*)

	Nutrient losses in runoff from: (kilograms/hectare/year)		
Nutrient indicators	**Pasture**	**Pine forest**	**Native forest**
Total (Kjeldahl) nitrogen[1]	10.76	0.76	0.83
Nitrate nitrogen (NO_3-N)	1.19	0.55	2.84
Total nitrogen[2]	11.95	1.31	3.67

[1] Total Kjeldahl nitrogen (TKN): organic nitrogen and ammonia
[2] Total nitrogen (TN): Total Kjeldahl nitrogen + nitrate nitrogen + nitrite nitrogen

On hill country, nitrate-contaminated groundwater often surfaces in seepage zones just above river terraces or in stream banks. On flat and gently rolling land groundwater will often remix in the stream or drain channel itself, especially when the water table is high. Sites that are frequently irrigated often experience the worst nitrate contamination. When soil is porous (such as pumice or riverbed gravels) the problem can be at its worst (see *Case Study 2*: Dairying and border-dyke irrigation along the Waikakahi Stream).

The symbiotic nitrogen fixation of pasture clovers adds 1.1 million tonnes of nitrogen per annum to New Zealand pastures, over seven times the amount of nitrogen fertiliser applied deliberately to pastures each year (Hedley et al, 1990).

Animal urine contains high concentrations of nitrogen in the form of urea. When deposited on the soil, in a compact “urine patch”, this urea is rapidly converted to nitrate at concentrations considerably in excess of pasture requirements. At mid-Canterbury stocking levels, grazing stock deposit urea-nitrogen in their urine at a rate of 40–70 kg of N/ha per year (Quinn, 1979). Urea readily converts to nitrate, and because it is deposited in concentrated spots of about 500 kg N/ha, pasture cannot utilise it and it is rapidly leached through the soil and into shallow groundwater.

Direct dung and urine deposition in streams

Livestock with free access to waterways add concentrated nitrogen through their dung and urine. Cattle and deer like to congregate in the stream channel, especially in summer, to keep cool. This often coincides with periods of low flow. Sheep usually only stand in the water when there is no alternative water supply. As a consequence, their contribution to elevated stream nutrient levels is likely to be less than that of cattle.

Artificial drainage channels can cause drainage waters to bypass riparian zone soils. Because the concentrations of nutrients in groundwater are reduced within this zone, it is reasonable to assume that sub-surface drainage works have increased nutrient (especially nitrogen) levels entering our streams and rivers.

Many agricultural streams may not register excessively high nitrate levels, but this should not be used as an excuse to avoid improved nitrogen management. Consideration needs to be given to the downstream cumulative effects of nutrient contamination in rivers and especially in lakes and estuaries.

Spray application of dairy effluent

In many parts of New Zealand dairy farmers are being encouraged by regional councils to spray their cowshed effluent back onto the paddocks rather than leaving it to be processed in a series of oxidation ponds. Well managed land-based applications have less impact on surface and groundwater quality than the outflow from oxidation ponds. Maori are also likely to advocate for the investigation of land-based disposal options, due to the offensiveness of direct discharge of effluent directly to waterways.

For any detrimental environmental effects of land-based spray application to be minimised the method and volume of application needs to be carefully managed. It is important to note that if the nutrient component of the effluent applied is greater than the capacity of the pasture to process it, and/or if the volume of liquid applied at any one time is likely to create surface runoff, then the net effect could be worse than the outflow from oxidation ponds. If effluent is applied at a maximum loading of 150 kg N/ha per year, the need for nitrogenous fertiliser applications will be lessened.

Photograph 3: Irrigation, especially on porous soils, can greatly increase nitrate leaching to groundwater which in turn can lead to stream water contamination. The spraying of effluent onto pasture increases the risks further, especially when irrigators are poorly managed or maintained, as is the case in this photo.

Nitrogen contamination of streams is most likely to occur where:

- high levels of nitrogen, well in excess of plant needs, are present in the soil (particularly as a result of high fertiliser rates)
- soils are very porous
- irrigation water is applied excessively
- wetlands have been drained (and their denitrification properties lost)
- subsurface drainage (eg, mole, tile, or novaflow) systems bypass riparian wetlands
- too much fertiliser application adds nitrogen directly to waterways
- livestock, especially deer and cattle, have free access to streams.

Nitrogen effects

In addition to causing profuse plant and algae growth, sustained high levels of ammonia can be toxic to fish and in extreme cases, humans nitrates consumed by bottle-fed babies during the first six months of life may cause what is known as "blue baby" syndrome, which occurs when blood haemoglobin is converted to methaemoglobin reducing the oxygen carrying capacity of the blood. Contaminated water containing nitrates and nitrites can also be poisonous to livestock. The toxicity of a given concentration of ammoniacal nitrogen increases as the pH and temperature of the water increases.

The Ministry of Health (1995) has set the maximum safe level for nitrate nitrogen in domestic water supplies at 11.3 g/m^3 (equivalent to 11.3 mg/L), and at 30 g/m^3 for livestock consumption.

3.3.2 Phosphorus

The principal sources of elevated phosphorus levels on agricultural soils are application of phosphate fertiliser and dung from livestock. During periods of summer lowflow agricultural streams may have high phosphorus levels and support heavy growths of algae and other aquatic plants. In one trial catchment at Purukohukohu (Cooper and Thomsen, 1988), pasture lost 15 times more phosphorus than did the native forest and pine production forest catchments (see Table 3).

Table 3: Phosphorus losses in runoff to streams in the Purukohukohu experimental catchments *(Cooper and Thomsen, 1988)*

	Nutrient losses in runoff from: (kilograms/hectare/year)		
Nutrient indicators	**Pasture**	**Pine forest**	**Native forest**
Dissolved reactive phosphorus	0.37	0.04	0.02
Total phosphorus	1.67	0.1	0.12

Increased phosphorus contamination in streams is very closely related to increases in sediment concentrations (Rodda, 1998) (see Figure 6). This is because phosphates most commonly attach to clay and other soil particles which are then carried by water (as suspended sediment). Consequently, phosphorus loss from pasture to stream is greatest where surface runoff and erosion are most likely. Surface runoff occurs either because rainfall intensity exceeds soil infiltration rates, or because groundwaters rise and emerge at the soil surface (waterlogged or saturated soils).

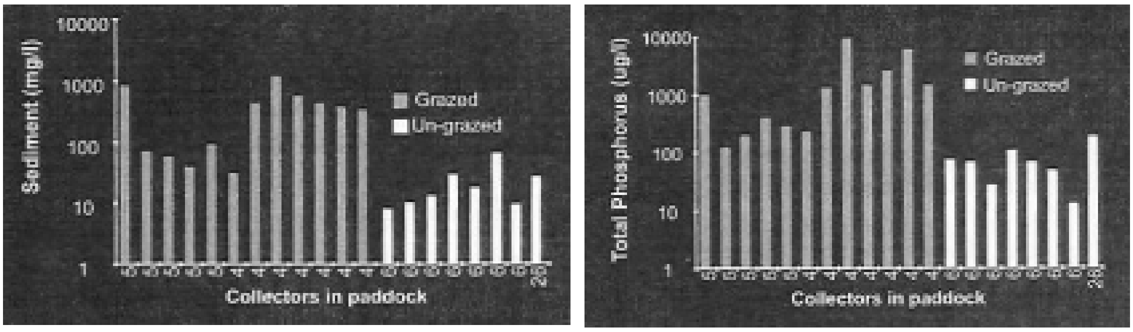

Figure 6: Diffuse source pollution (*Quinn and Thorrold, 1998*)

Recently-grazed pastures appear to have elevated levels of phosphorus and sediment loss compared to ungrazed pastures. The speed of water runoff (and hence its erosive capacity) is probably greater because there is less grass to intercept and slow down the passage of water and more soil is likely to be exposed. This is likely to be increased where pastures are overgrazed and where soils become waterlogged and pugged.

The greatest phosphorus runoff concentrations tend to occur directly after fertiliser applications and are generally substantially greater than those found in runoff from highly fertile soils. Thus careful management of the timing of fertiliser application is important.

Like nitrogen, phosphorus can also be introduced to streams as dung where livestock, especially cattle, have direct access to streams. In addition to dung, cattle encourage streambank erosion which accelerates sediment and hence phosphorus contamination. Cattle by their sheer weight tread and expose soil as they walk on and over river banks. Rain and elevated water levels erode the soil away where it is exposed and carry phosphorus with it.

Phosphorus contamination of streams is most likely to occur where:

- streams receive discharge from oxidation ponds
- low soil permeability encourages increased surface runoff
- soil erosion is a significant problem
- streambank erosion is occurring
- phosphatic fertiliser is applied to saturated soils
- high levels of phosphorus are present in the soil
- fertiliser is applied directly onto waterways
- subsurface drainage systems feed directly to waterways
- dung is deposited by livestock with free access to streams.

Phosphorus effects

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* provide DRP values, above which excessive algal (periphyton) growth may be promoted. Chapter 3 provides default DRP trigger values for lowland and upland rivers. These guidelines are available in the Ministry's website at: www.mfe.govt.nz/publications/water/anzecc-water-quality-guide-02/index.html

New Zealand Periphyton Guideline - detecting, monitoring, and managing enrichment of streams provides mean monthly DRP values for a range of average days of accrual. These guidelines are available on the Ministry's website at: www.mfe.govt.nz/publications/water/nz-periphyton-guide-jun00.shtml

Phosphorus sorbed to soil particles, which generally enters stream water in surface runoff, can also contribute to increasing nutrient loadings and consequently lead to nuisance plant growth, especially on lake beds where nutrients accumulate in the deposited sediment. Phosphorus does not occur in our waterways in concentrations that are toxic to humans and other animal life.

3.4 Contaminants from agriculture: sediment

Estimates of rates of soil loss (Crossan, 1995; Pimental et al, 1995a, 1995b) suggest that six tonnes of soil per hectare are lost annually from pastureland, 13–17 tonnes per hectare from cropping, and only half a tonne from undisturbed forest. If we assume an average annual soil loss on New Zealand farm and exotic forest land of six tonnes per hectare then we are losing one 10-tonne truck full of topsoil every three seconds. This is six times higher than the average rate of soil formation.

Generally the greatest sources of sediment entering farm waterways come from accelerated erosion.

Suspended sediment levels are generally two to five times higher in streams draining pasture catchments than those draining native forests (Quinn, 1997). This has been attributed in part to the increased volume and velocity of surface runoff, a legacy of forest clearance on farmland; and in part to the impact of livestock and farm grazing and soil management practices. Where the bedrock is particularly erodable, the sediment loads may be even greater. Deforestation has the greatest impact of all and can increase sediment loads a hundredfold.

Surface soil loss to streams is likely to be most significant where:

- farm livestock, especially deer and cattle, cause soil compaction and treading damage to pasture, with the greatest impact being on steep and saturated soils
- excessive grazing of pasture and high stocking rates occur on wet, steep, and erosion prone land
- poorly drained and maintained tracks feed runoff directly to streams
- cultivation leaves soil bare for prolonged periods, especially over winter and spring.

3.4.1 Mass movement

The risk of mass movement (soil slip, earth slip, debris avalanche, earthflow, and slump erosion) increases with slope, degree of weathering of the underlying rock, and the relative impermeability of the subsoil. Consequently, there is considerable regional variation in susceptibility to mass movement, with areas of softer rock (such as that in parts of the east coast of the North Island) exhibiting severe erosion as a result of forest clearance and subsequent farming.

Mass movement can contribute large quantities of sediment to stream systems. At the Whatawhata Research Farm, west of Hamilton, one massive slip with an eroding surface area of 0.41 hectares put 11,000 tonnes of sediment into the stream over nine months.

3.4.2 Treading and pugging

Treading damage occurs when the soil surface becomes exposed through removal of pasture cover. Pugging refers to the destruction of surface structure of wet soils by stock or traffic. Both can result in reduced water infiltration capacity and increased surface runoff. The extent of soil damage and consequent sediment and nutrient runoff depends on the intensity of grazing, the weight of the animals, slope steepness and the ability of the individual soil type to withstand animal treading damage under wet winter conditions. On predominantly volcanic ash soils, soil damage due to treading on easy slopes (15–24°) had no effect on runoff of sediment and nutrients, whereas on steeper slopes (28–39°), treading damage generated greater losses of soil, phosphate and nitrogen (Nguyen and Sheath, 1998).

Photograph 4: High sediment concentrations in streams are far more likely to occur when pasture is damaged and pugging occurs, especially on slopes. Not only does it lead to soil loss but also to serious production loss. The pasture will take considerably longer to recover than pasture grazed in a more controlled fashion.

The heavier the animal the greater the potential damage. Therefore, bulls and steers are individually likely to cause more damage than cows and substantially more than sheep. The exception to this are deer. Although considerably lighter than most cattle, deer have a strong behavioural tendency to damage large areas of pasture, particularly in wet or water seepage zones, on erosion-prone faces and around fence margins. (This is dealt with in more detail in *Case Study 6*: Deer farming and riparian management in Southland.)

3.4.3 Roading and tracking

Farm tracks and roads can be a significant source of sediment (and nutrients) for hill-country streams. They are generally highly compacted and so water tends to flow along them as opposed to being absorbed. As essential arteries for the movement of livestock they accumulate manure, which is in turn carried down by runoff.

Roads and tracks tend to traverse slopes, so they intercept runoff from upslope and channel it; and frequently they lead to streams carrying the runoff that flows along them. There are several management practices available to reduce the impact of tracks on stream sediment and nutrient levels and these are discussed in a later section.

3.4.4 Streambank erosion

The removal of the original dense indigenous vegetation has left most agricultural streams more vulnerable to increased streambank erosion. This risk is further accentuated by increased flood flows, as there are no longer headwater forests to intercept rainfall and surface runoff.

Free access of livestock, particularly cattle, to streams and stream banks greatly accelerates streambank erosion:

- intensive grazing of streambanks reduces the ability of the bank to resist the erosive forces of flooded streams
- treading and pugging of banks exposes soil to erosion
- livestock accessing the stream for water tend to cut their own access tracks which can become drainage points for runoff and sources of sediment and nutrient to the stream
- the sheer weight of cattle, in particular, can accelerate streambank slumping.

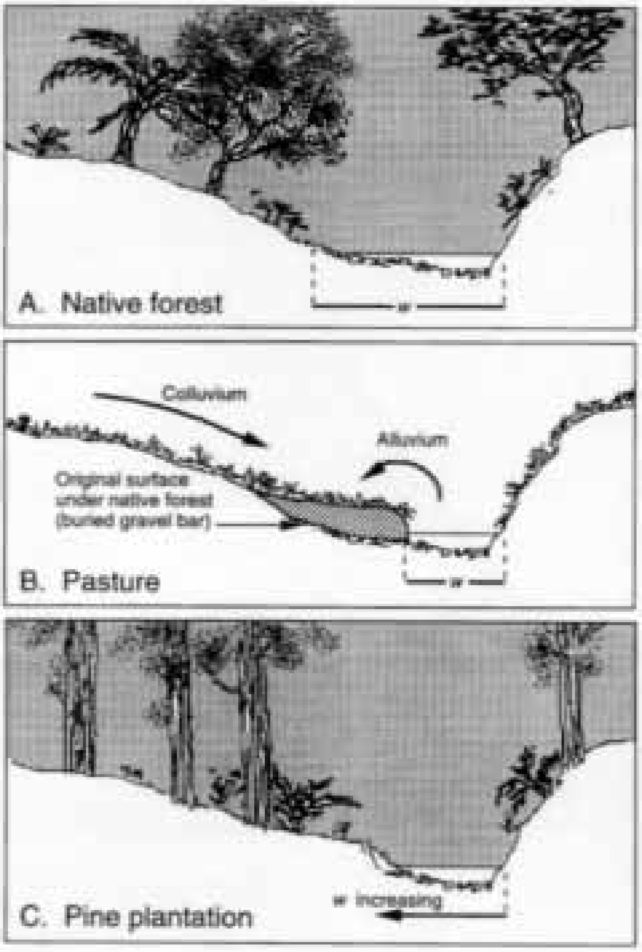

Figure 7: Conceptual model of the channel form of small streams at the same cross-section in different riparian vegetation. **A:** steady-state stream cross-section in native forest; **B:** steady-state stream cross-section in pasture; and **C:** stream-bank recession in a pasture stream planted with pines (pictured after canopy closure). Sediment stored in the pasture stream banks is indicated in Panel B. (*Davies-Colley, 1997)*

Cattle entering the stream channel over several days have been shown to increase the number of bank erosion sites by 66 percent and typically increased water turbidity from a background level of 5–15 NTU to levels of 65–85 NTU and on occasions as high as 230 NTU (Stassar and Kemperman, 1997).

Generally, stream channels flowing through pasture are narrower than those flowing through forest (native and exotic), and this is most pronounced in small streams where forest streams can be twice as wide as those in pasture. Pasture stream channels appear also to be more deeply incised (see Figure 7). As a result of the narrowed channel, and perhaps also because of increased floodflows due to deforestation upstream, pasture stream waters are faster flowing.

The replacement of riparian forest with exotic grasses has had an important impact on channel narrowing. Pasture grasses trap sediment derived from floodwaters and from catchment erosion and consolidate it into soil. The net result is new stream banks built inside the original active channel, the narrowing of the channel, and the accumulation of stored sediment which is highly erodable if exposed by livestock or bank undercutting. There is some suggestion that reafforestation of narrow agricultural stream banks may lead to a reversion of the channel back to a forest shape, with erosion of the banks and channel widening, especially if streambank grasses have been shaded out (Davies-Colley, 1997).

3.4.5 Cultivation

Sediment contamination of streams is most pronounced on cropping and horticultural land where cultivation occurs close to the edge of streams and drains, and where depressions that serve as temporary drainage channels during rain are cultivated and left exposed to surface runoff (see Figure 8). The impact of these cultivation practices is magnified where cultivation takes place on a slope: the steeper and longer the slope the greater the erosive force of the runoff.

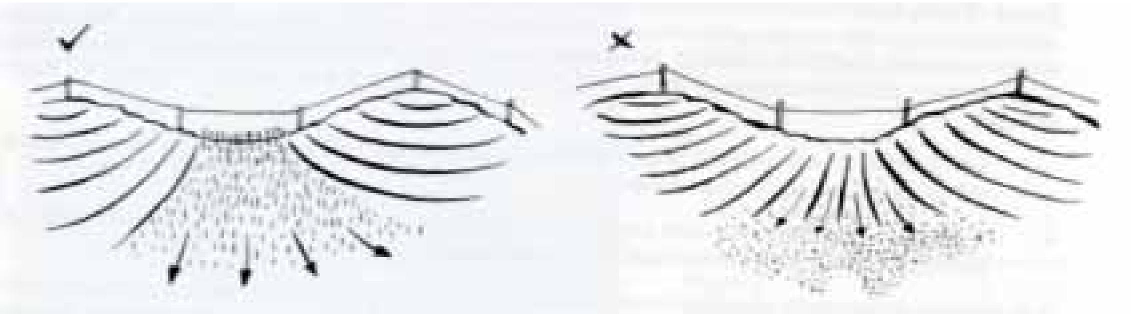

Figure 8: Grassed waterways – in hollows, not bare soil *(Hicks, 1995)*

Other practices that can increase surface runoff and/or sediment (and nutrient and pesticide) contamination of stream waters include:

- cultivation up and down a slope, as opposed to contour cultivation
- excessive cultivation, resulting in soil compaction and the development of pans and crusts
- soil cultivation when soil moisture levels are too high (wet or saturated soils) or too low.

3.4.6 Suspended solids – effects

High suspended solid levels impacts aquatic life in several ways:

- high turbidity can reduce photosynthesis and overall productivity of aquatic communities by reducing light penetration
- poor visibility can promote emigration and loss of animals from affected areas
- sediments can clog the food filtering or trapping mechanism of aquatic insects
- sediments can coat stone surfaces and clog the small spaces on the stream bed critical for stream plants and animals
- suspended materials may kill fish at very high concentrations:
  - reduce fish growth rate and disease resistance
  - prevent successful egg and fry development
  - modify movements or migrations, or reduce food availability
- fish efficiency in catching prey may also be reduced.

3.5 Faecal contamination

Faecal contamination is a serious problem because of the immediate risk it poses to human and stock health. Faecal material is a source of bacterial, protozoan and viral pathogens. Agricultural streams and rivers in the Wellington region were found to have faecal coliform levels 20 times greater than those draining indigenous forest catchments (Smith et al, 1993).

Faecal coliform bacteria, *E. coli* and enterococci bacteria are most commonly used in water monitoring as indicators of the potential presence of harmful pathogens. All are ordinary bacteria that live inside human and animal intestines and pass out in faeces; the assumption is that if they are present the more harmful micro-organisms are also likely to be present. If these bacteria are present at all, water is classified as unfit for human consumption (Ministry of Health, 1995). As bacterial density increases, water is progressively classed as unfit for shellfish harvesting (for marine waters above a measurement of 14 faecal coliforms per 100 ml of water), contact recreation (above 277 enterococci/100 ml[3]) and sheep and cattle consumption (above 1000/100 ml for marine waters and 410 *E. coli* for fresh water).

Animal faecal material enters streams in four ways:

- directly by stock with free access to stream channels
- transport of dung in surface runoff
- oxidation pond discharges
- in localised cases, where shallow groundwaters beneath intensively farmed areas have become contaminated by leached faecal material.

Faecal contamination is likely to be greater where:

- stream water is the only source of drinking-water for stock
- stock must cross streams to reach pastures or milking sheds on the other side
- there is no alternative shade available to stock in the summer
- stocking rates are high
- there are cattle and deer
- streams are not fenced from stock.

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3 The Ministry of Health and MfE recently (November 1999) published the Recreational Water Quality Guidelines, which use *E. coli* as the indicator of choice for freshwaters and enterococci for marine waters.

Pathogen concentrations reaching and contaminating streams and rivers (and ultimately lakes and estuaries) may increase when:

- livestock are intensively farmed (ie, high stocking rates)
- surface runoff is high due to low soil permeability, overgrazing, soil saturation, steepness and long slope lengths
- riparian wetland areas and seepage zones have been drained
- no riparian vegetation remains to filter out contaminants from surface runoff
- heavy rain follows a period of dry weather
- sub-surface drainage systems have been put in place
- oxidation ponds discharge directly to streams.

When pathogens enter waterways through animal waste and human sewage, they pose a risk of illness to swimmers, recreational users and shellfish eaters.

Many animal pathogens may occasionally be transmitted animal to animal via water. In most cases water is not recognised as the main vehicle of transmission. A recent study the ‘Bad Bugs programme’ considered various pathogens, the criteria for selection in the study included potential transmission in water, and zoonotic potential. The main pathogens considered were: *Cryptosporidia* a protozoa which causes diarrhoea, *Salmonellae* a bacteria which cause stomach upsets and dysentery; *Giardia* a protozoa which can cause diarrhoea, stomach cramps, bloating, dehydration and nausea; *Fosciola* a parasite; and the bacteria *Leptospira* and *Campylobacter* which causes stomach ailments in people and abortions in sheep and cattle.

Faecal contaminants are also a potential health risk to livestock. Reduced growth, ill-thrift or mortality may result from the transmission of pathogens in contaminated waters.

The direct detection of pathogens in faecally contaminated waters is not feasible for routine assessment, as the pathogens occur intermittently, are diverse, and some are difficult or impossible to recover from waters. Tests for indicator bacteria levels can be carried out to determine the risk of pathogens being present, rather than testing for individual pathogens.

3.6 Chemical contamination

Pesticide contamination of waterways is most likely to occur next to land used for commercial cropping, market gardening, orcharding and other horticulture. Sheep dip sites also offer the threat of contamination. Pesticides can enter waterways in three ways:

- they can leach through the soil to groundwater
- they can be carried in surface runoff (bound to fine soil particles)
- from direct contamination due to spraydrift.

Modern agricultural chemicals (herbicides, insecticides, and fungicides) are generally less persistent and more specific in their activity than those used in the past. In contrast with the organochlorines used during the 1950s, 1960s and 1970s (such as DDT), most modern pesticides are not bioaccumulative.

But while modern pesticides are generally less persistent in the environment, many are highly toxic to aquatic and terrestrial organisms (including humans). Each class of pesticide has its own maximum acceptable value (set by the Ministry of Health), below which the water is considered to be of drinkable quality. Separate toxicity levels for aquatic organisms have also been developed for some chemicals.

3.7 Stream temperature and shade

Many streams running through pasture have a surprisingly high levels of shade (50–70 percent shade). This is largely provided by stream banks and by bank vegetation, but this is considerably less than in forested streams, which typically have shading of 95–98 percent. Open streams with low banks and a complete lack of riparian vegetation can be expected to have considerably lower than 50 percent shady (Collier et al, 1995; Rutherford et al, 1997). The amount of shading has a significant impact on water temperature with pasture streams having daily maximum temperatures that are 6–7°C higher than forest streams, and daily mean temperatures 2–3°C higher.

The temperature of farm waterways varies with climate, elevation, groundwater inputs, shade and flow, as well as from human activities such as farm discharges and water abstraction. Water temperature also varies from season to season and throughout the day.

Water temperature is an important determinant of habitat suitability for a wide range of aquatic flora and fauna. In particular, brown trout need water temperatures below 10°C (for rainbow trout, below 12°C) during the winter spawning season. Many important aquatic insects die when temperatures exceed 23°C. In many parts of the country, pasture stream temperatures often exceed 20°C during the summer, and can exceed 25°C.

Small streams heat up and cool down more rapidly than larger streams and hence may be more responsive to changes in riparian shade. A small stream (with a flow of, 0.013 m^3 per second) passing from native bush into pasture may warm by up to 10°C within a few kilometres, while a larger stream (0.250 m^3 per second) may take over 40 km to warm up by 10°C.

Computer modelling predicts that shade levels of about 75 percent are sufficient to maintain water temperatures comfortably below 20°C (Rutherford et al, 1997). In the very smallest streams, the shade from stream banks, the surrounding land and overhanging plants may be sufficient to maintain acceptable water temperatures, whereas in larger streams (flows of hundreds of litres per second) tall riparian vegetation is necessary to lower water temperatures.

As well as influencing water temperature, shade, by reducing light levels, has a direct impact on aquatic plant growth. A reduction in stream lighting will produce an equivalent reduction in aquatic plant production. A major concern with open stream reaches is that algae and aquatic plants may grow to nuisance levels. This is more likely in agricultural catchments where waters are enriched by nutrients.

Generally, aquatic weeds require at least 30 percent of the light of an open site to sustain growth. Thus, shading of 70 percent or more can be expected to reduce growth of these plants. The complete elimination of macrophytes is, however, probably not desirable as they greatly increase habitat diversity and can be the main substrate for invertebrate colonisation in open streams with sandy bottoms and little woody debris. Fifty percent shading has been suggested to retain a desirable macrophyte level. Nuisance filamentous and mat growths of algae are also likely to be eliminated by shading of 70 percent or more, although shade levels of 90 percent are necessary to restore periphyton biomass to the low levels typical of forest streams.

Adequate stream shade is important to instream life because:

- it helps to keep summer maximum water temperatures below levels that can threaten the tolerances of fish and invertebrate life
- it can reduce nuisance growths of algae and aquatic plants.

Excessive shading may:

- eliminate macrophytes from streams (their retention can be important for stream function in soft-bottomed streams)
- result in loss of stream bank groundcover plants thus increasing bank erosion.

3.8 The impact of flow regime on water quality

The flow regime of a river will vary with the season and other activities such as abstraction, which in turn effect water quality. To learn more about this readers are referred to The Ministry for the Environment publication "Flow guidelines for instream values" Volume A and B (1998).

4 Managing the problem

4.1 Overview

> *"We may conclude then that in every respect the valley rules the stream. Its rock determines the availability of ions, its soil, its clay, even its slope. It is also clear that changes in the valley wrought by man may have large effects. Some are obvious and need not to be stressed here; but others may be very subtle."* (Hynes, 1975)

What options are available to landowners to stop the deterioration of water and waterways? The management and improvement of water quality and instream and riparian habitat is as much about managing land and water away from the riparian zone as in it. Streams are the product of their catchments and are the link that unites all the different components of the catchment.

While a healthy riparian area can be very effective at intercepting and filtering out contaminants, an acceptable improvement in water quality and instream habitat cannot usually be achieved by riparian margin management alone. More often than not, improved land management, that is, improved grazing, fertiliser or cultivation practices, and riparian retirement together will create the greatest improvement.

Rivers, lakes, wetlands and estuaries tend to reflect and magnify the management problems of the catchment. Once water has entered these larger water bodies it is much more difficult to do anything about improving its condition. Instead, the greatest return, in terms of potential improvements in water quality, for cost and effort expended, comes in improving the headwaters and subcatchments of all the small tributary streams.

> *Successful riparian management requires long-term commitment, support and input from the landowner(s).*

The most effective and innovative riparian management options are usually developed where there is a thorough understanding of:

- local farm (and forest) management practices
- local climate, soil, water and vegetation
- riparian area and riparian vegetation function
- the sources and causes of the riparian problems, at the local and catchment level
- the need for management/implementation strategies to be well-planned and well-resourced

and where farmers participate in developing the solutions.

> *The consequences of an impact on water quality will be felt by all those utilising the water downstream.*

Effective freshwater management and the improvement in water quality and aquatic habitat ultimately requires the buy-in of all landowners in the catchment. One person and one property's good practices cannot undo the bad practices of other properties in the catchment. However, the consequences of bad practice, even if the impact on a stream is small, can be cumulative, so that a catchment of moderately healthy tributary streams can create a downstream river, lake or estuary that is polluted.

4.2 Planning and prioritising

There is no single problem with our water and waterways, so consequently there is no single answer to the problem. There are typically many contaminants that affect water quality and riparian and aquatic life, several sources of each contaminant, and different ways each can enter our waterways. It is vital that we understand the causes and sources of water quality and habitat problems before devising an effective strategy for improvement.

The following questions need to be addressed before a course of action can be planned:

1 What do I – and my community – want from my stream?

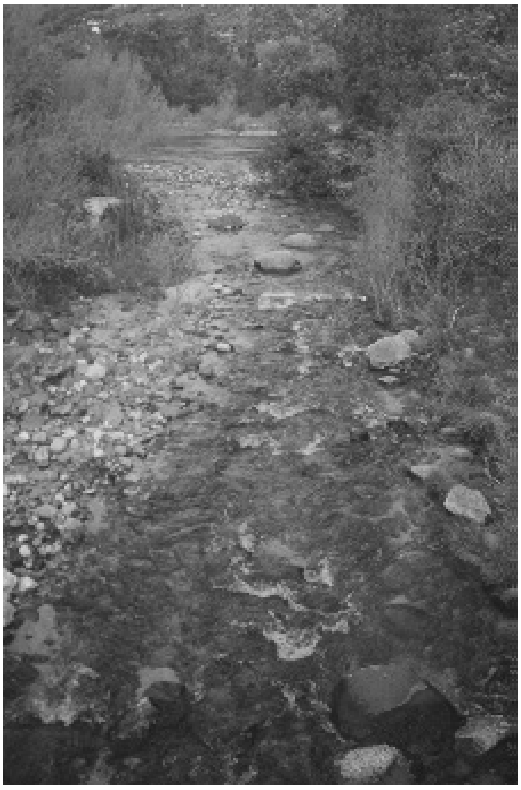
For example, is the stream to be mainly used for recreation or water supply purposes? These factors need to be taken into account: if the main purpose is to be for, say, fishing, then plantings would need to be done so that access is still suitable. Once the final use is decided the best management option to achieve that purpose can be determined.

2 What condition is my stream in?

This question needs to be addressed both on the local scale and on the catchment scale.

This information is quite often hard to obtain or simply not available. Some possible sources of information are:

- regional council, local authority or district council
- local landcare groups which monitor streams
- local anglers
- conduct your own stream monitoring programme
- conduct your own visual assessment
- the New Zealand Stream Health Monitoring and Assessment Kit or SHMAK (NIWA Technical Report 40) was developed for landowners to be able to collect scientifically robust data on stream health. Contact Christchurch (03 343 7890) or Hamilton (07 856 7026) NIWA offices if you wish to purchase a kit, alternatively NZ Landcare Trust Christchurch (03 349 2630) for further information. Some Regional and District Councils have kits that can be loaned to landowners or landcare groups.



Photograph 5: Two farm waterways, one with clear, unturbid water, light algal growth and no sediment. The other has murky water, with heavy algal growths. The bed of the drain cannot be seen.

Look for:

- cloudy, muddy or discoloured water, all of the time or periodically, eg, after rain or when cattle cross the stream at milking time
- excessive streambank erosion, especially during high flow
- substantial growths of algae, slime and other aquatic plant life
- damage to stream banks caused by stock
- accelerated soil erosion during rain
- fish, crayfish, eels in the stream
- small insects visible under stones in the stream.

For current and historic information, approach iwi and other local landowners, particularly older people who have been in the area for a long time.

Tiaki may be able to provide information about the following questions:

- What was the river like historically?
- What did the river and the valleys look like?
- What aquatic life was present?
- How did Maori use the river?
- How has the relationship with the river changed over time?
- What is the present state of these factors?

3 What problems are arising on my property, where are they arising and how are they reaching the waterway?

It is important to realise that even if your local assessment or monitoring suggests there are no serious water quality problems along your stretch of the stream, the cumulative effect of many minor inputs of contaminants can be substantial downstream, particularly in lakes and estuaries where sediment and nutrients tend to accumulate. Modern agricultural practices, by their very nature, generate unnatural excesses of nutrient, sediment, surface runoff and bacteria which invariably find their way to waterways. There is always something that can be done to reduce contaminant inputs to streams and groundwater.

In some situations the likely contribution of contaminants to a stream can be assumed without a detailed assessment of stream condition.

It is important to determine not only where the problem contaminants are coming from but how they are entering your stream or exiting your property. Without this knowledge an effective remedial management plan cannot be devised. Typically, contaminants will be generated from several sites on the property, with each site generating varying concentrations. The exposure of these areas of greatest concentration to one or more of the modes of contaminant transport will determine the sites that offer greatest risk to stream contamination. Landowners need to be able to identify the likely hotspots and how the contaminants are most likely to be carried to the stream or waterway.

4 How do I decide what to do first?

There are several aspects to be considered when determining priorities for action:

- What are the major catchment water quality issues and where can they best be managed?
- Where will the greatest reduction in stream contamination be achieved per unit effort?
- Where will the greatest improvements be achieved for least cost/effort?
- How will the possible courses of action impact on farm management?
- What on-farm productivity and profitability benefits, and asset improvements, can be gained from reducing contaminants?

Careful cost-benefit analysis needs to be undertaken for each management option. At the end of the day the net cost of remedial management will likely dictate what action is actually taken.

Realistic appraisal of how much is available to spend on remedial management is essential prior to the work being undertaken and prior to the proposed course of action being planned.

5 How does water management fit in with my other priorities?

Much of the remedial work associated with water and waterway enhancement involves the management of vegetation and can involve significant tree planting. With careful planning vegetation can be managed and trees and shrubs planted to perform many functions simultaneously including the improvement of water quality and riparian habitat. Shade, shelter, timber and firewood production, nut and fruit crops, enhanced native birdlife, native forest restoration, and landscape enhancement are all objectives that are compatible with improved stream and riparian management.

6 What resources are available?

In addition to personal resources, several regional and district councils offer a variety of forms of assistance to landowners wishing to undertake riparian management, erosion control and revegetation programmes:

- technical support – one-to-one advice, and technical support to landcare groups
- compilation of free or subsidised environmental farm plans (including riparian recommendations)
- partial or complete supply of fencing materials for retirement fencing (or it may be in the form of cash subsidisation)
- cash subsidisation of plant purchase for erosion control, riparian plantings and restoration of existing native bush remnants.

The assistance offered by regional and district councils can make a substantial difference to the affordability of riparian management programmes.

7 How will my changes affect land downstream?

An awareness of the interests of other parties and knowledge of the potential impacts of planned work on other members of the community will reduce the likelihood of future conflict. For example, planting can, for a time, lead to increased sediment discharge into a stream, so restoration plantings may have to be modified to lessen such impact.

Substantial riparian margin tree and shrub plantings can affect anglers' and the general public's rights to access to the stream. An awareness of these public rights and interests, at the planning stage, can ensure that everyone is accommodated.

8 How will upstream changes affect me?

In several situations the management options and techniques available to landowners will be limited by the state of the water entering their property from upcatchment. The most common example of this is in the middle and lower portions of river catchments where streambank erosion is severe and aggressive flood flows occur regularly. In such situations the planting of conventional riparian margin species to stabilise eroding banks will not work, and other species better equipped for this can be used. It is very important that landowners and their advisers fully understand the implications of upstream and upcatchment forces before riparian restoration occurs so that money and resources are not wasted.

9 What are the neighbours doing about water management?

There is little to be gained by fencing off and planting a riparian margin if across the stream the neighbour's cattle have free access to the stream and are able to cross it. Equally, effort and money spent restoring a wetland will be of little value if the neighbour immediately downstream is trying to drain their portion of the same wetland. The greatest improvements for the least cost will be achieved if neighbours and adjacent landowners in the same catchment can plan and undertake remedial action in a cooperative fashion. This can be achieved through the formation of a landcare group if desired but can also work effectively where communication is less formal but occurs on a regular basis (see later section).

4.3 Nitrogen management

4.3.1 Reduce nitrogen loss from soils

Nitrogen is most effectively managed while still on the pasture.

Nitrogen loss can be reduced by:

- by applying nitrogen fertiliser:
  - when the water table is not excessively high
  - when heavy rain is less likely
  - when grass growth is active
  - in quantities not in excess of plant requirements (taking into account the quantities of nitrogen likely to be derived from livestock, clover fixation and, where applicable, land-based effluent application)
  - ideally in split dressings to give the plants a better chance to utilise what is applied
  - not in areas of localised high nitrogen such as stock camp sites
  - not directly onto stream channels
- livestock management:
  - excluding from stream channels (especially cattle)
  - removing from saturated soils
  - excluding from wetlands, seepage zones and bogs so that a healthy cover of grasses and sedges can develop with improved capacity to denitrify nitrate inputs

- ensuring irrigation application is:
  - not close to the time of fertiliser application
  - not used to such excess as to cause surface runoff or raise the water table too close to the surface
  - used with care on porous soils.

4.3.2 Extract nitrogen from groundwater: the value of wetlands

Once nitrogen has found its way to groundwater, it can only then be treated where the groundwater reappears at the surface such as at springs, seepage zones and wet areas at the base of hills, and sometimes seepage zones along stream banks. The retention of these wet areas and the grass, rush and sedge vegetation that typically grows in them is essential if nitrogen is to be removed from the emerging groundwater that flows through them. Provided there is plenty of suitable organic matter, anaerobic conditions exist, and hydraulic conditions are such that suitable retention times exist, in excess of 90 percent of the nitrates in the incoming water can be removed.

Photograph 6: Well vegetated, saturated wetlands serve many useful purposes. They are habitat for birds and fish; nitrates can be removed by denitrification; sediment and phosphorus can be filtered out of the water; and water can be stored during times of rain preventing flooding downstream.

Riparian vegetation, especially the more deeply rooted trees and shrubs, may perform some role in extracting nitrogen from groundwater for plant growth, although the quantities removed are small compared to the process of enitrification. Deep rooted trees may be counter-productive in or beside wetland areas as they can cause the drying of wet areas.

4.3.3 Remove livestock from streambeds: the merits of trough water

The first priority for the management of nutrient contamination should be excluding livestock from streams and stream channels. This can be one of the single most effective actions that a farmers can take to reduce nutrients in a farm waterway.

Some farmers carefully place water troughs to achieve greater pasture utilisation. If a trough is positioned near an area not previously well-grazed, stock can be enticed to form camp sites in that area and graze there. This can assist nutrient management because most defecation and urination occurs near camp sites.

4.4 Phosphorus management

Loss of phosphorus is closely tied to soil erosion. Fertiliser phosphorus quickly binds to soil particles and is carried in suspension in surface runoff, so efforts to reduce soil loss in surface runoff will reduce phosphorus loss as well. Phosphorus loss from soil and contamination of waterways can be reduced by care in fertiliser application and livestock management, as well as by soil and pasture management.

Once phosphorus enters surface runoff, the opportunities to extract it again are confined to situations where the speed of surface water flow is sufficiently reduced for the sediment and attached phosphorus particles to settle out of suspension. Long and dense swards of grasses, rushes or sedges (called "filter strips") growing on relatively level areas offer the greatest opportunities for this to occur. Suitable sites where this could occur include:

- wet areas and seepage zones that are located in zones that also intercept surface runoff
- river terrace fans where surface runoff is distributed diffusely over a wide relatively level area rather than through a narrow, steep channel
- riparian filter strips comprising dense stands of grasses, sedges and rushes
- benches or sills higher up in valleys and gullies.

Filter strips are most effective at removing coarse particles from overland flow. Studies have shown that 90 percent of sediment can be withheld by an effectively constructed filter strip (Smith, 1989). The most effective filter strips are relatively long, densely covered with grasses and sedges, and lie on land of very gentle slope. The Department of Conservation riparian guidelines (Collier et al, 1995) give details for effective use of filter strips.

Photograph 7: Graham McBride, a dairy farmer west of Hamilton, has experimented with the construction of narrow ungrazed grass filter strips across a face prone to excessive surface runoff. He has noticed that the long grass significantly reduces the speed of surface runoff. The water emerges from the downslope side as a mere trickle compared to that entering the filter strip. This strip, because it is so narrow, will have little capacity to hold sediment, but by reducing the speed of water flow, it will reduce the erosive force of the runoff quite significantly.

Stands of riparian trees and shrubs are not as effective as grasses and sedges at intercepting and removing phosphorus. The closed canopy of dense riparian bush tends to exclude many of the grass-like groundcovers that are necessary to trap sediment and phosphorus contained in surface runoff. In addition, runoff will normally be concentrated in channels by the time it passes through the riparian strip to the stream itself. This substantially reduces the ability of any vegetation to filter out suspended particles as well as increasing the likelihood of riparian erosion. Where riparian vegetation is being restored and there is an opportunity to intercept surface runoff a dense planting of sedges and rushes along the landward side of the riparian zone would be most effective.

Sediment and phosphorus accumulate wherever they are trapped, and storage sites can become phosphorus saturated. To prolong their life a means of removing phosphorus needs to be introduced. Controlled and periodic mowing or grazing (during periods when surface runoff is less likely) of grass filter strips could be useful in this regard.

Phosphorus can also reach streams by livestock defecating in the water and by sediment loss associated with streambank erosion. Removal of cattle from stream water and stream banks will reduce both as sources of phosphorus.

Phosphorus loss from soil and contamination of waterways can be reduced by the following practices:

- Livestock management:
  - keep livestock, especially cattle, out of streams and drains
  - avoid overstocking and resulting soil treading and pugging damage, particularly on wet soil.
- Fertiliser application:
  - do not apply fertiliser to saturated soils
  - take care to apply fertiliser when heavy rain is less likely
  - do not apply fertiliser directly to streams, wetlands or other unproductive areas
  - apply only sufficient phosphorus to meet plant needs.
- Soil and pasture management:
  - if possible, avoid overgrazing which will expose more soil to erosion by surface runoff
  - keep stock, especially cattle, off wet and saturated soils and avoid pasture damage caused by pugging and treading damage
  - take extra care with stock and pasture management on soils of low permeability as they are more prone to soil erosion.
- Stream and streambank management:
  - fence out all livestock or at least cattle from waterways, or, if streams are the only viable water source allow access only to small portions of the streams where streambank damage is less likely
  - keep livestock off soft and unstable stream banks
  - maintain a healthy cover of grasses and sedges on stream banks, especially on portions prone to erosion during high water flows, eg, outside bends.
- Wetland and filter strip management:
  - preserve, restore or recreate wetland zones and their vegetation especially where they also lie in the path of surface runoff channels
  - create and maintain temporary or permanent grass or sedge filter strips on relatively level areas over which surface runoff passes.
- Drainage and effluent management:
  - where possible allow subsurface drainage waters and oxidation pond discharges to flow through a wetland before entering a stream.

4.5 Sediment management

Riparian vegetation, filter strips and wetlands will not in themselves be sufficient to reduce stream sediment loads to acceptable levels where hillside erosion is severe. The causes of the erosion itself must be treated and that is a topic too large to be covered adequately in this publication. In some of the worst areas for soil erosion, such as parts of the East Coast, North Island, restoration of a forest cover is possibly the only means of significantly reducing soil erosion.

In areas where the possibility of soil erosion is not so great, there is much that can be done to reduce soil loss, assist farm productivity and benefit water quality and instream habitat. Streambank erosion has already been mentioned; sheet erosion and erosion resulting from mass movement are also significant.

4.5.1 Sheet erosion (sheetwash)

Sheet erosion – the diffuse loss of soil to surface runoff – removes most soil from farmland. Soil loss due to sheet erosion can be significantly reduced by sensible management of soil, pasture and livestock.

Soil loss due to sheet erosion can be significantly reduced by sensible management of soil, pasture and livestock:

- Reduce pasture damage:
  - keep stock, especially cattle and deer, off wet and saturated areas where treading and pugging damage can occur
  - avoid overgrazing of pasture especially during winter when surface runoff is greatest and soil moisture levels are highest.
- Minimise and slow down surface runoff:
  - allow pastures to grow longer during the wet season on areas where runoff is most substantial
  - establish temporary or permanent filter strips on more level portions of the hill to intercept and slow down surface runoff.
- Intercept runoff before it enters streams:
  - utilise existing wet areas, or restore old wetlands where they lie in the path of surface runoff channels
  - establish filter strips on the landward edge of riparian margins and on river floodplain fans where water flow is diffuse rather than channelled
  - construct sediment traps or ponds in the path of significant runoff channels.
- Construct and maintain adequate farm road drainage and crossings:
  - where possible, construct farmroads and tracks on stable sites and keep gradients as low as possible
  - provide plenty of cut-offs to channel off any water flowing down tracks before the volume and velocity of the runoff becomes excessive.

Photograph 8: Farm tracks can be a significant source of sediment and nutrient runoff. Frequent cut-offs are advisable on tracks such as this so that water and sediment are channelled off the track and back onto pasture before the volume and velocity of runoff become too great. Sediment traps along the sides of steep tracks will also reduce the velocity of water flow. Sediment traps must be regularly emptied if they are to function properly.

- Maintain the cut-offs regularly and use flumes and piping to carry runoff onto stable vegetated ground
  - – construct sediment traps adjacent to streams (but out of the flood channel) to collect sediment in the road runoff and prevent it from flowing into the stream
  - – construct bridges or culverts at regularly used river crossings.

Photograph 9: Silt or sediment traps can be effective damage control devices where high amounts of sediment erosion can be expected. Cultivated areas, such as this vegetable growing property near Pukekohe, and forestry areas during harvesting are two situations where silt traps could be used. Silt traps must be regularly cleared of accumulated sediment to be effective.

- Minimise the risk of soil loss during cultivation:
  - use minimum tillage or zero tillage for land with a high risk of erosion due to runoff
  - retain a substantial well vegetated riparian strip between cultivation and streams and drains
  - incorporate crop residues to increase/maintain soil permeability
  - on slopes cultivate across the contour rather than up and down the slope
  - leave uncultivated gullies and areas where surface runoff is more prevalent
  - avoid excessive cultivation that can result in the formation of pans
  - avoid cultivation when soil moisture levels are too high or too low
  - rip wheel tracks to encourage infiltration and reduce runoff
  - use winter cover crops instead of leaving paddocks fallow.

4.5.2 Mass movement and fluvial erosion

Steepness, soil type, geology and vegetation cover will determine the susceptibility of hill-country farmland to slips, earthflows and gully erosion. Insensitive livestock and pasture management can increase that susceptibility. Many of the practices listed above as means to reduce sheet erosion apply equally to the various forms of mass movement (earthflows, slumping, rilling and gully erosion).

Once a slip, earthflow or an eroding gully has occurred, however, the control of the erosion can be considerably more difficult. Retirement from grazing and the planting of deep-rooting trees may be the only two management options available, other than engineering works, eg, fluming, diversions, or detention dams.

4.6 Management of faecal contamination

Faecal contamination of waterways can be managed by reducing overgrazing, and soil treading and compaction, so as to reduce surface runoff and the concentration of dung in surface runoff. If surface runoff is occurring then filter strips, wet seepage zones and riparian margins can be used to intercept and filter out the solids.

Trapped faecal organisms are killed in filter strips by exposure to environmental conditions (eg, sunlight and dehydration). Therefore, filter strips do not become saturated with faecal material, as they can with phosphorus.

Excluding livestock from streams will prevent direct contamination.

4.7 Chemical management

Contamination of waterways is most likely to occur as a result of careless or excessive application. Sensible and effective application will not only benefit the environment but reduce management costs.

Management precautions include:

- spray only at rates recommended
- avoid spraying when rain is likely
- take all necessary precautions to minimise spray drift – it is often the fine spray that you can't easily see that is doing the damage, eg, do not spray in windy conditions
- do not mix, fill or empty spray containers in stream beds nor use contaminated containers to source water from the stream
- where practical, targeted or spot application of a chemical is preferable to broadcast application
- retain uncultivated and unsprayed riparian buffer zones around waterways
- increased monitoring of insect and fungal pests can result in sprays only having to be applied when they are required as opposed to being used regularly as a preventative measure. The consequences of this and other integrated pest management strategies are less cost (due to less chemical used), less environmental contamination, less likelihood of the development of pest resistance, and less impact on "friendly" insect predators
- locate sheep dipping, and sheep dip disposal, well away from waterways.

4.8 Managing several contaminants at once

Many landowners need to manage or reduce the input of several contaminants. Because of the different sources and causes of contamination, this can seem costly. There are, however, several practices that will help reduce many potential contaminants.

Sensible soil, pasture and livestock management can prevent a significant proportion of the potential contaminants ever entering the system, and this will also benefit farm profitability. Nitrogen, phosphorus, sediment and faeces are all vital to farm productivity. The more that can be retained and utilised on the farm, the less is the need to apply expensive fertilisers.

Management practices can involve focus on soil, livestock, fertiliser use and application, and tree planting and maintenance. Any combination of these is likely to reduce streamwater contamination. Many are relatively inexpensive, and virtually all can become a standard part of day-to-day farm management.

Because of the intensity of most farm production and the high levels of nutrients and excrement produced, it is inevitable that even under the most careful management that contaminants will at times enter surface water or groundwater and that can threaten water quality and the health of instream inhabitants.

4.9 Managing and restoring aquatic habitat

4.9.1 Shade and temperature

Reintroducing shade along stream channels will restrict the growth of aquatic plants and algae, will lower water temperature, especially the critical summer maximum, and will improve the habitat for shade preferring indigenous invertebrate and fish life. The obvious cure is planting riparian vegetation, but how much shading is required and how can this best be achieved?

Shade levels of about 70 percent will probably reduce summer maximum water temperatures to acceptable levels in warmer parts of New Zealand (Rutherford et al, 1997); shade levels a little lower than this will retain some macrophyte growth, which is important substrate for invertebrate colonisation in sandy bottomed streams.

Trees planted along one bank only can often create sufficient shade (about 70 percent) if planted along the northern side of a stream. Because summer is the critical time when shade is most required, both deciduous and evergreen tree species can be used. Deciduous trees offer one advantage in that they provide full shade during summer when the stream most needs it, but allow increased light levels during winter when groundcover bank plants may otherwise be excluded.

It is more beneficial to cool smaller upstream reaches than larger ones (Rutherford, 1998). In these situations it may only be necessary to plant portions of the stream in order to keep stream temperatures low. Outside bends and other areas prone to bank erosion could be left in grasses and other groundcovers such as flax, while stream straights and inside bends could be planted in shading vegetation.

If streambank erosion is a potential threat, the following practices are suggested:

- Keep shade levels no higher than 50–70 percent.
- Keep shade levels low on portions of the stream where bank erosion is most likely (eg, unstable inset terraces) but increase shading elsewhere.
- Plant the north side of the stream only, leaving adequate light on the opposite bank for grass growth.
- Use deciduous trees to provide critical summer shade but allow sufficient light to groundcover plants during low-light winter conditions.
- Select bank stabilising species tolerant of lower light levels.
- Plant single or double tree rows that will allow side light to sustain bank ground cover while shading the stream channel.
- On small, narrow streams plant long grass or sedge species (eg, *Carex* species.) which will provide useful shade and function as a filter.

If a period of streambank erosion and channel widening during channel adjustment is acceptable then shade levels approaching 90 percent will result in the restoration of light and temperature conditions close to native forest levels.

4.9.2 Plant selection

Data from plantation forests indicate that:

- 15–20 year old eucalypts spaced six metres apart will create 70 percent shade
- 15–20 year old pines at 7–14 metre spacings will create 70 percent shade
- the maximum shading under any density of eucalypts is 80 percent
- pine trees spaced at 3.5–10 metres apart will create 90 percent shade.

The impact of harvest on the stream (by way of shade loss and, perhaps, increased streambank erosion) needs to be carefully considered before the trees are planted.

Where riparian vegetation forms a closed canopy over smaller streams a high level of shading can be assumed, but a closed canopy will not be possible over wider streams.

There may be some advantages for the stream ecosystem in replanting with native as opposed to exotic trees. The more continuous leaf fall patterns of native vegetation appear to be preferable as a food source for stream invertebrates compared with deciduous exotic species (Scarsbrook et al, 1998). The diversity of terrestrial insects available as food for fish may be greater from native species, which are also essential components of the riparian margin if indigenous biodiversity is to be increased.

Food supplies

Riparian vegetation is an important source of energy (organic carbon) for invertebrates and fish in streams and rivers. The carbon comes from dissolved organic matter, including leaves, bark, wood, and terrestrial animals. The removal of riparian vegetation or a reduction in the diversity of vegetation can have a significant impact on instream fauna.

As is the case with native plant restoration on most land types, the establishment of a diversity of plants representing different species, plant sizes and forms and with different leaf shapes will improve the variety, continuity and abundance of food available to instream fauna. Exactly what plants are established when will depend on the conditions of the particular stream.

Included in the variety for the enhancement of instream food supply should be:

- a mixture of species with soft leaves (eg, wineberry, tree fuchsia, koromiko, mahoe and pate) which break down rapidly, and hard leaves (eg, titoki, karamu, lemonwood, kohuhu, five-finger and kamahi) which break down over longer periods
- a mixture of species with larger leaves (eg, wineberry, karamu, tree ferns, five-finger and pate) which are more likely to stay resident in a stretch of stream for longer, and small leaves (eg, koromiko, red matipo, and kohuhu) which are more inclined to be moved downstream
- a selection of shorter lived species (eg, wineberry, karamu, koromiko, and kohuhu) which are more likely to supply rapid sources of woody debris to the stream
- trees and shrubs with a weeping habit over stream edges (eg, toetoe, *Carex* species, flax, kowhai, native brooms and tree ferns) to supply a variety of insects and other invertebrates for fish.

4.10 Maintenance of farm drains

Farm drains and ditches are the most widely used mechanisms to channel surface runoff and reduce the water-table on farmland. Drains are particularly effective at these roles. However, they also act to concentrate nutrients, sediment and agricultural chemicals. The build-up of sediments and nutrients frequently triggers the growth of nuisance aquatic plants. Excessive plant growth and sediment deposition may reduce the efficiency of the drain to drop the farm water-table and channel floodwaters. The effects of sediment and vegetation are seldom quantified, but can result in significant losses in drain flood capacity (Hudson, 1998a). As a result, most farm drains require regular maintenance. The most commonly used maintenance procedures are; mechanical clearing with an hydraulic excavator (a "digger"), by hand or with a weed-boat cutter, and chemical spraying with herbicides (eg, glyphosate, diquat and paraquat). Both mechanical clearing and use of chemicals may have significant negative effects on the flora and fauna of farm drains.

4.10.1 Effects of mechanical clearing on the biota of farm drains

Mechanical clearing has several direct and indirect impacts on the water quality, plants and animals in farm drains.

Direct effects:

- Sediment and aquatic plants are physically removed from the drain.
- Sediment is suspended and turbidity in the drain increases dramatically.
- The physical shape and flow characteristics of the drain are changed.
- Invertebrates, fish, eels and crayfish are physically removed with the sediment and plants.

The indirect effects are:

- disturbance of sediment re-suspends agricultural chemicals and sprays which have accumulated in the sediment
- loss of food for some bird species (eg, swans)
- removal of all plants results in loss of overhead cover essential for regulating water temperature (Rutherford et al, 1997)
- loss of plants that are habitats used by invertebrates and many native fish (eg, inanga, giant kokopu, shrimp)
- disturbance of drain-bed substrate, including removal of cobbles and gravels which are essential spawning sites for fish species (eg, trout)
- physical damage to the drain margins and banks by the excavator's increasing bank instability and erosion
- many nuisance aquatic plant species grow from plant fragments that float downstream or are spread from one waterway to another by the excavator.

The negative impacts of mechanical excavation digging can be reduced by:

- not digging out the entire length of the drain. Instead dig out reaches of 10-20 m and leave 10-20 m undisturbed, or
- only digging out one side of the drain, so that half of the width remains undisturbed
- avoiding excavation during peak fish spawning and migration and bird nesting periods (see Table 4)
- leaving spoil close to the drain bank so that fish removed in the spoil have a chance to re-enter water via the shortest route
- ensuring that diggers are thoroughly cleaned, to reduce the risk of accidental spread of nuisance plants
- ensuring that exposed drain banks are seeded and re-planted soon after clearing
- during maintenance of smaller drains, placing straw bales or filter fabrics downstream to reduce sediment.

Table 4: Summary of likely fish spawning and riverine bird nesting periods for species found in farm drains in the Southland region *(compiled by Hudson, 1998b)*

Common name	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Fish species												
Lamprey												
Longfinned eel												
Shortfinned eel												
Common smelt												
Inanga												
Giant kokopu												
Common galaxias												
Torrentfish												
Common bully												
Redfinned bully												
Bluegulled bully												
Upland bully												
Black flounder												
Brown trout												
Bird species												
Black shag												
Little shag												
White-faced heron												
Australian brown bittern												
Mallard												
NZ scaup												
Grey duck												
Marsh crake												
Pukeko												
NZ kingfisher												
Welcome swallow												
Fernbird												

4.10.2 Effects of chemical spraying on the biota of farm drains

Herbicide sprays are frequently used to control aquatic plants because sprays are significantly cheaper than mechanical digging. A wide range of herbicides are available, and spray selection usually depends on whether marginal, emergent or submerged plants are targeted. Chemical spraying has several direct and indirect impacts on the water quality, plants and animals in farm drains.

Direct effects:

- Aquatic plants are killed rapidly.
- Sprays such as diquat and paraquat are toxic even at low concentrations (eg, 0.05 mg/l) to some freshwater invertebrates eg, amphipods (Burnett, 1972, Hunt, 1974).

The indirect effects are:

- loss of food for some bird species (eg, swans)
- loss of overhead cover essential for regulation temperature
- loss of plants which provide habitat for invertebrates and many native fish (eg, inanga, giant kokopu, shrimp)
- deoxygenation of water caused by decomposing plants
- sprays such as diquat and paraquat may accumulate and persist in drain sediments for one year or more (Brookes, 1988).

The negative impacts of herbicide sprays can be reduced by:

- not spraying the entire length of the drain. Instead spray reaches of 10-20 m and leave only 10-20 m, undisturbed
- only spraying the centre of the drain where faster flows occur, so that the edges of the drain remain undisturbed to provide cover, food and habitat
- spot spraying, to avoid spraying riparian vegetation
- not spraying during peak native fish spawning and migration periods
- using contact herbicides (eg, “Torpedo”) which act directly on plant tissue.

4.10.3 Alternative drain maintenance practices

Maintaining drain hydrology by naturalising the stream

Many drains are straight, channelised and have a uniform depth to ensure rapid runoff of floodwaters. However, most natural streams and rivers curve or meander, have gentler slopes on at least one bank, and have variable depth with rapids and pools. These features of natural streams can frequently be incorporated in farm drains without affecting the ability of the drain to reduce the farm water-table or carry high flows.

Reducing sediment and contaminants

Virtually all forms of agriculture result in increased erosion and the flow of sediment and contaminants into farm drains. Fencing and planting of riparian zones will frequently reduce these inputs, however subsurface drainage often reduces the effectiveness of riparian vegetation as a buffer. The transport of sediments and contaminants in the drain can be reduced by creating "sediment sumps" (eg, deeper, wider pools) or small "wetlands" at intervals along the drain (Brookes, 1988; Nguyen et al, 1998). Sediment and contaminants will settle in these sumps or wetlands while also acting as buffers for high flows.

Controlling aquatic plants

Aquatic plants grow vigorously when high nutrient concentrations and highlight levels occur in the drain. Some control of weeds can be gained by:

- riparian planting to filter nutrients
- planting trees on the north bank of a drain to provide shading. This has been shown to reduce the growth and density of some nuisance weeds (Crabbe, 1994; Scarsbrook et al, 2000; Young et al, 2000)
- the use of herbivorous fish eg, grass carp is being tested. However, these fish only feed in warmer water (eg, upper North Island), and may become a pest if released into natural waters (Rowe and Schipper, 1985).

Further recommendations

- Large woody debris provides good cover for invertebrates and fish. If these are not liable to cause damage to culverts or bank erosion during high flows, then leave them in place.
- Culverts and floodgates should be designed to allow fish passage.
- Culverts should be large enough to carry high flows and not act as choke points for floodwaters.
- Create wetlands or deep, wide pools at regular distances along the drain, to attenuate floods, filter sediment and contaminants and provide more variable instream habitat for invertebrate and fish.

Summary of effects

Table 5 summarises the effects of various drain maintenance options for land and in-stream management.

Table 5: Summary of the effects of different drain maintenance strategies on land and stream management (+ indicates beneficial, – indicates negative effects)

	Mechanical clearing	Herbicide sprays	Hand clearing	Cutting boat	Riparian fencing	Riparian planting	Wetlands	Sediment sumps
Land management								
Farmland productivity					–	–/+	–	
Farm costs	– – –	–	– –	– –	–	–/+	–	–
Field erosion					+	++		
Bank erosion	– –				+	+++	++	
Nutrient runoff	–				+	+++	+	
Stream management								
Flood flows	+++	++	++	++	+	+++	++	+
Weed problem	+++	++	++	++		++		
Nutrient transport	– – –	– –	– –	– –	+	+	++	+
Sedimentation	– – –	–	– –	– –	+	+	++	++
Turbidity	– – –		– –		+	+	+++	++
Substrate quality	– – –		– –				++	+
Overhead cover	– – –	– – –	– –	– –		++	++	
Invertebrate communities	– –	– –	– –	– –		+	++	+
Fish communities	–		– –	– –		+	++	+

5 Restoring the vegetation

5.1 Riparian planting zones

The riparian margins of agricultural streams typically have four distinct planting zones.

5.1.1 Flood zone

This includes the lower (toe) and middle portions of the bank which receive floods frequently and which bear the brunt of flood flows. In some streams the entire bank area falls into this category. In spring-fed streams, this zone may be small. The key planting management issues in this zone are that:

- plants chosen for planting must be able to resist the forces of floods and remain anchored in the ground (both as seedlings and mature plants)
- plants must be able to withstand periods (possibly up to several days) of complete immersion
- plants must also be able to withstand long periods of heat and dry soils during the summer.

Ideally, flood zone plants should also contribute to the provision of shade and food to the stream and improve the micro-habitat so that other plants can establish.

5.1.2 High bank zone or bank crest

This is the area above the level of frequently experienced flooding and extending over the crest of the bank. The key plant management issues here are that:

- plants must be able to withstand occasional flooding
- plants in this zone should be deep rooting, to anchor the bank against collapse resulting from undercutting at the bank toe
- plants can be taller in this zone to provide some shading effect and organic matter to the stream but should not be prone to toppling.

5.1.3 Flood plain or river terrace

This zone extends from where bank collapse is no longer a risk back as far as the floodplain extends or as far as the riparian planting is to occur. It is typically fertile, often quite sheltered from wind and usually has reasonable soil moisture levels. A diverse variety of riparian trees and shrubs can be grown in this zone.

5.1.4 Inland filter zone (or strip)

In natural riparian ecosystems, this zone exists at seepage sites, riparian wetlands and areas where surface runoff collects before entering the stream.

In agricultural riparian margins many of these wet areas have been drained or excluded as a consequence of riparian zone reduction. Grass or sedge strips can be established along the landward face of the riparian zone to serve this function.

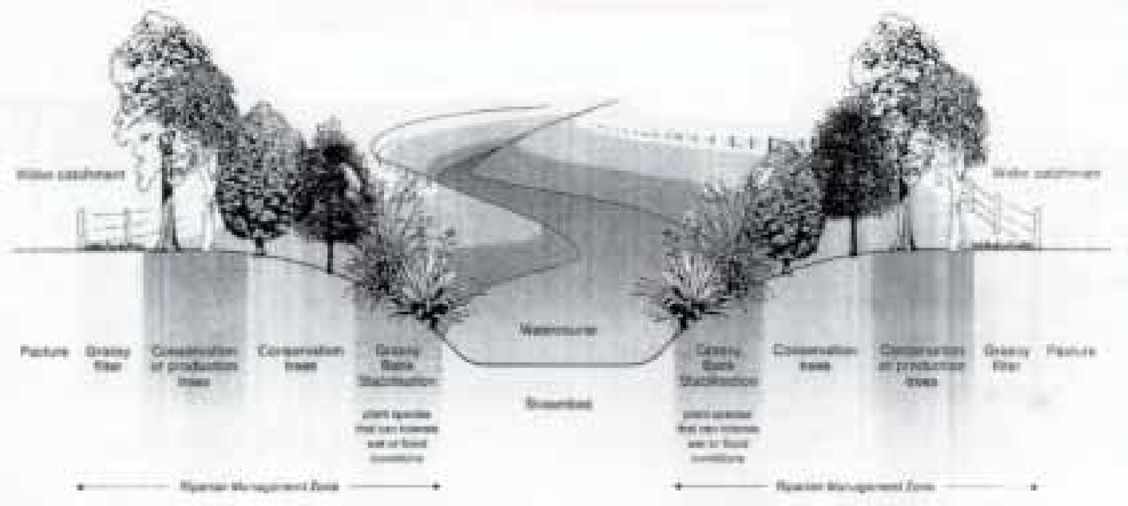


Figure 9: Cross-section of an optimal riparian buffer strip.

5.2 Management objectives

Riparian zones should be designed to achieve multiple objectives. Riparian zones can assist with:

1. restoration of instream habitat
2. restoration of indigenous terrestrial riparian habitat
3. stabilisation of streambank erosion
4. interception of agricultural contaminants
5. assistance to farm management (eg, shelter and shade)
6. economic return
7. recreational and aesthetic enhancement
8. protection and/or restoration of areas and resources of cultural significance
9. restoring waterway health.

Categories 1 and 2 are largely compatible and can be managed for concurrently if the riparian margin is wide enough. Management for Category 3 will vary significantly depending on the extent of erosion and local geology. Category 4 will require the use of different plant assemblages and may require a wider zone if undertaken in addition to Categories 1 and 2. Categories 5, 7 and 8 can, with good planning, be accommodated within any of the others, while Category 6, a productive return, may not be compatible with creating indigenous terrestrial habitat and may require additional planting to function as a means of intercepting contaminants.

5.3 Restoring indigenous terrestrial habitat

Natural, unmodified riparian zones typically extend from the stream edge, across the floodplain to the base of the hills and, in steeper catchments, at least part way up the slopes. Prior to human settlement, much of this was forest covered and there was a wide diversity of plants. Canopy tree species such as rimu, totara, miro, matai, kahikatea, and rewarewa grew widely in these zones, and other tree species such as cabbage tree, kowhai, ribbonwood, lacebark, putaputaweta and several tree ferns were also characteristic.

Under these trees and around the edges a rich subcanopy of *Coprosma* species, mahoe, pate, kamahi, tree fuchsia, five-finger, wineberry and many other species abounded.

The associated riparian wetlands and seepage zones were often more open, with flax, toetoe, sedges and rushes predominant, as well as a scattering of cabbage trees and divaricating shrubs such as mingimingi and twiggy tree daisy. The margins of streams flowing through unforested areas were dominated by tussocks and sedges.

Plant assemblages similar to these can be restored over time to most modified riparian zones. However, the order in which these are established will vary with the degree of modification and the proximity of healthy native forest.

5.3.1 Restoration from open pasture

Dense exotic pasture swards sitting on highly fertile soils are particularly difficult environments in which to restore native vegetation. Even our more aggressive native colonising species are not effective competitors with exotic pasture species when left to their own devices. Seedlings will not germinate in pasture from naturally dispersed seed until the pasture has begun to become less dense and the soil fertility has lessened as a result of leaching and plant utilisation. This may not occur for five years or more following retirement from grazing, and even then only a select few fast-growing native species – such as karamu, kanuka, manuka, wineberry and flax – can occupy mineral (low organic content) soils in competition with exotic grasses and weeds.

Appropriate plant and species selection, effective site preparation, appropriate planting technique, timing and spacings, and methodical site maintenance (releasing and pest control) are vital.

Photograph 10: Open pasture can be one of the most hostile environments in which to plant native trees and shrubs: exposure to wind, sun and frost, competition from thick and vigorous pasture grasses, and easily accessible to rabbits, hares and (when poorly fenced) to livestock. Spot spraying of planting sites before planting and regular releasing (up to 3–4 times per growing season on warm, fertile sites) is necessary.

5.3.2 Replenishing scrub and restoration under tree canopy

Groves of adult cabbage trees, kowhai and totara, exposed to grazing and with no undergrowth, are common sights along riparian margins. Restoration of these trees and conversion to a native bush requires:

- fencing to exclude all livestock
- planting of the outer margins of the stand with colonising small trees and shrubs to reduce the impact of the edge effect on the forest interior
- possible replenishment planting of the interior with sub-canopy and forest interior plants if there is not a ready source of seed nearby
- regular pest control.

Frequently, riparian bush areas have little in the way of canopy and climax tree species such as rimu, totara, kauri and tawa remaining. If an area of forest containing these species does not occur close enough by to allow plants to re-establish naturally, then seedlings will need to be planted. Reverting scrub areas of kanuka are ideal sites for the re-establishment of native tree species.

5.3.3 Stabilising streambank erosion

Vegetation is the key factor in controlling bank stability, but inappropriate vegetation can reduce stability and promote erosion in some situations. The introduction of tree species over existing grasses can lead to exclusion of the grass species because of shade and thus increase streambank erosion, unless shade tolerant ground cover is established.

Along a stream reach there are usually three distinct zones, each requiring different approaches:

- **outside bends**, where the erosive forces of water are at their greatest and streambank erosion is most likely to occur particularly during floods. Planting on these areas to anchor them against erosion is most critical.

- **inside bends**, where the erosive forces of water are minimised. Sandy deltas or beaches will often establish there. It is important these deltas are left free of obstructive vegetation to provide space for free water flow during floods (sedges and rushes that lie flat when overtopped by flood current may be tolerable).
- **stream straights**, where the forces of water are generally equal on both banks, and much less than on outside bends. As a consequence, bank erosion is usually less than on an outside bend.

Grasses, sedges, rushes and other dense groundcovers are effective at colonising and stabilising collapsed or deposited sediments characteristic of many open pasture stream banks. However, the level of protection is poor where the plant cover is damaged by heavy grazing, tracking or shade. These plants provide little protection on steeper banks where bank sediment is less stable and where the stream tends to undercut the bank below water level.

Larger trees can stabilise higher banks through their deep, robust rooting system. Those species which can rapidly produce a deep and extensive root system (eg, poplars and willows) are of greatest value, whereas heavy trees with shallow or confined root systems (eg, pines) can be easily undercut and encourage rather than prevent erosion.

Pasture streams with badly eroding stream banks require trees and shrubs with vigorous growth and extensive rooting systems. Several varieties of willows and poplars are known to perform well in such sites; however, several traditional varieties can choke stream channels, potentially deflecting flood flows into banks, exacerbating erosion. Care should be taken to use recently developed hybrids that are not prone to uncontrolled spreading.

No native species have been found to match the vigour and deep root systems offered by willows and poplars; while the extensive fibrous root systems of tree ferns are excellent for streambank protection, they are not as deeply rooting as willows and poplars. Kanuka and manuka are often found remaining along stream banks despite stock tracking and grazing, but their role in streambank stabilisation has not been well-researched.

The spacing between trees can be as important as the depth of tree root extension where bank erosion is an issue. Trees spaced so far apart that their roots do not intermesh can, in fact, encourage accelerated bank erosion. In floods, water can glance off the roots of one tree and hit the less-resistant area of bank between the root systems. Poplars and willows on stream banks and on eroding hill country need to be planted no more than 6–10 metres apart to enable them to form a complete blanket of intermeshed roots.

Exotic grasses may be the only option on the banks of some pasture streams where sediment deposits have accumulated and stream channels have narrowed, but several New Zealand sedges – especially *Carex secta* – are particularly well-equipped to withstand the extremes faced on stream banks. They serve many beneficial functions:

- *Carex secta* bends and lies flat on the bank surface when submerged reducing the surface area exposed to the current and reducing the likelihood of it being dislodged
- it grows in very wet and waterlogged conditions as well as in very dry soils – common seasonal conditions on open stream banks.
- Once established and when planted close together (one metre spacings), these sedges slow down the water flow along the stream margins.
- Their extensive mop of fine leaves is effective at trapping the seed of other native species, and their umbrella-like growth form protects seedlings.

- Their drooping habit helps provide shade to streams and supplies leaf litter and terrestrial insects as food for instream life.
- *Carex secta* is favoured habitat for several native water birds, providing shelter and nesting habitat, and for whitebait while spawning.

Photograph 11: *Carex* sedges such as these pictures beside the Ahuriri River in inland South Canterbury provide excellent shade, habitat and food for the occupants of streams and wetlands.

5.4 Planning and planting riparian zones

5.4.1 Zone width

The first question asked is usually "how wide do I need to make the riparian planting?" But there is no ideal width. The natural width of the riparian zone varies enormously between streams and catchments and even along the length of a stream. The width will vary from a few metres for a narrow stream to many metres for wider channels.

Photograph 12: Riparian buffer widths will vary with stream size and the type of farming occurring in the catchment.

For the restoration or re-establishment of an area of indigenous riparian habitat, the zone needs to be of sufficient size to attract native birds and insects and sufficiently wide for there to be a bush interior not exposed to the climatic extremes of the bush edge (termed the "edge effect"). Later successional species of plant (including subcanopy species such as tree ferns, kanono and pate, and canopy tree species such as totara and kahikatea) prefer protected interior zones. They are less likely to regenerate naturally if a protected forest interior does not exist, nor will they arrive if birds are not attracted to the bush.

River channels are natural corridors for the movement of animals from one large area of bush to another. By their very nature riparian areas are long and narrow and so have a sizeable edge. This exposes each area to greater risk of weed invasion, its animal inhabitants to increased predator pressure, and its vegetation to increased risk of devastation by flood and wind. The greater the area of continuous bush cover, the lesser the risk to the flora and fauna.

The greatest benefit to indigenous biodiversity is likely to be gained where riparian bush restoration is focused on restoring existing bush remnants and on joining existing fragments.

5.4.2 Plant selection

Most riparian margins on farmland are devoid of any native trees, or at best have a few cabbage trees or totara as isolated remnants of the past. In these situations the riparian margin will either consist of pasture grazed to the water's edge or a narrow strip of rank grass (and perhaps some gorse and blackberry) behind a temporary fence.

Open pasture riparian margins are especially hostile to native seedlings, so particular care should be taken when selecting the species, grade and condition of seedlings for planting. Even where remnants of riparian forest and scrub remain, growing conditions can be harsh. Many of the species that are naturally present in riparian areas are not tolerant of these extremes because they are secondary species that grow in the cover of other plants. Ask your nursery or plant supplier for hardy colonisers and enquire as to the tolerances of species offered. Native plants planted in open pasture riparian areas must also be tolerant of periodic immersion and strong enough to withstand the force of a flood current.

Within the constraints of the site conditions, as wide a range of native species as possible should be planted. They should represent a range of leaf shapes, growth habits and flowering and fruiting times and types. The fruit and nectar should attract a variety of birds, reptiles and insects and lend themselves to a variety of dispersals – wind, bird and water. This will encourage further new species, which will continue the process of succession.

Purchased seedlings must be well-hardened to the conditions that will be experienced at the planting site. If this has not been done at the nursery then the plants should gradually be hardened while still in their containers and prior to planting, or many of them will die.

Heights of 30–50 cm are an adequate size for the planting. Smaller seedlings will require considerably greater post-planting maintenance, and larger plants are substantially more expensive yet provide no significant improvement in survivability. Fast-growing coloniser species are more likely to survive when planted as smaller grades (30–40 cm) from small containers (root-trainers and small planter bags – sizes PB3/4, PB2 and PB3), whereas slower growing species including many canopy tree species are better planted as larger 40–50 cm seedlings (PB3 or PB5).

Ecosourcing: To enhance the chances of survival and reduce the risk of diminishing the local gene pool of naturally occurring native plant populations, the use of plant material that has been grown from seed procured from naturally occurring local plant stock is suggested. If the desired plant species are not available from local commercial nurseries, it is suggested that plants be selected from locations with similar growing conditions. Care should be taken if plants are sourced from far afield – plants within a single species differ markedly in their tolerances from one region to another. Bay of Plenty sourced kanuka, for example, are hit badly by hard Taupo frosts when the local Taupo stock are untouched.

Compared to species such as pines, native plants are generally very site specific. Minor variations in topography, aspect, soil drainage, micro-climate and existing vegetation alter the natural or "ideal" assemblage of native species. When the right species are matched to the right micro-sites native species can grow quickly. However, there is little readily accessible information that matches native plant species to their site preferences. Native plant suppliers or a local native plant expert may be able to provide advice on this.

Initial colonising species are equipped to occupy open and hostile sites, and once they have made the environment more hospitable to plant life their role is less important. Thus, many native colonisers are reasonably fast growing and shortlived.

5.4.3 Planting time

Planting of natives is best undertaken between late April and mid to late September. This puts less stress on the plants and allows them to adapt to the site before warmer temperatures and increased day length encourage faster growth. In areas that do not experience cold, harsh winter conditions (snow or heavy frosts) and on more sheltered sites, planting is often best completed during autumn (late April to early June).

Autumn-planted natives will often be in better condition to react to favourable growing conditions in spring and will certainly be better equipped to cope with an early drought. In those areas that experience harsh winters, planting is best completed in spring. Planting will need to be carried out early in spring in those areas prone to early droughts.

5.4.4 Plant spacings

The spacing of planted seedlings should take account of the need to achieve a closed plant canopy as quickly as possible, to exclude invasion by weeds and reduce post-planting maintenance costs. Planting too close together, however, can exclude slower growing species and thus create gaps for exotic weed. Both these aspects are important to consider.

Most colonising native trees and shrubs will form a canopy within three to five years when planted at spacings of 1.5–2 metres. Natives spaced at three metres or more may never form a continuous canopy, in which case bare ground remaining between plants is very quickly occupied by weeds such as pampas grass and blackberry. At two-metre spacings, 2500 plants would be required to cover one hectare; at three-metre spacings, only 1100 plants are necessary. The latter spacing leaves 1400 plant sites unoccupied, and at least some of these will become occupied by weeds, whose control may cost as much as the trees would have cost in the first place.

Smaller grasses, sedges and groundcovers may need to be planted as close as one metre. This is particularly so with *Carex secta* when planted on erosion-prone stream banks where a dense, complete canopy is necessary to deflect the water current and protect the soil.

The space requirements of mature trees should not govern the spacings used at planting time. Maturity for many species does not occur for many years, and during their immature growing phases many species grow faster and taller when in the close company of other plants. Rimu at 50-cm spacings or less, for example, has been shown to grow as fast over the first 10 years of life as saplings at considerably greater spacings. The closely spaced trees were generally taller with less lateral branching than the more distantly located seedlings.

Natural competition and exclusion will gradually favour the most vigorous growers. The establishment of a closed canopy as quickly as possible after planting is generally more important to the development of a piece of bush than the gradual loss of some individuals due to competition for space. Natural mature age spacings should only be considered at planting time with colonising species that reach maturity rapidly. For example, planting of a mix of karamu, koromiko and flax at one-metre spacings could lead to the unnecessary death of some within three to four years of planting, whereas 1.5–2-metre spacings should allow all plants to survive.

5.5 Site preparation and maintenance

Most native plants are highly palatable to livestock and other animal pests, and for maximum survival and optimum growth rates native seedlings require regular releasing from grass and weed competition.

5.5.1 Fencing

All areas to be planted in native plants should be fenced to exclude stock prior to planting. Cattle can devastate growing seedlings in 30 minutes. Ideally, fencing should be of permanent materials because areas planted in natives will need to be permanently retired.

Traditional one- or two-row shelter belts require fences on both sides to exclude stock. The integration of riparian plantings, tree crops, shelter and shade into multi-functional single stands can greatly reduce establishment costs.

Cattle farmers can use electric fencing, and (at a cost of only $2-$5 per metre) a well-built and well-maintained two- or three-wire electric fence will generally be effective at excluding cattle. Cattle should be excluded from streams because of the damage and level of contamination they can contribute; they must also be excluded from all tree plantings; permanently from natives and until exotics are well-established.

Sheep farmers face higher fencing costs because sheep can only be effectively excluded with eight- or nine-wire post and batten fencing. Sheep certainly pose less threat to water and stream quality than cattle if they have direct access, and providing shade and trough water away from the stream margin will help to reduce their impact. However, if trees are to be planted, especially natives, sheep will also have to be excluded.

5.5.2 Site preparation

Weed removal

Planting areas will need to be cleared of weeds and competing grass prior to planting. Weeds and grasses grow more rapidly than many native species and can very quickly smother young seedlings and/or out-compete them for water and nutrients. Cleared weed and grass-free circles (of no less than one metre diameter) should be established around each plant site before planting begins, and invasive weed species such as gorse and blackberry are best cleared from the site altogether if possible.

Glyphosate type herbicides (such as Roundup) are recommended for weed removal on larger planting projects. Manual (using a spade) weed and grass clearance can be achieved on smaller sites. Glyphosates are generally accepted as the safest sprays to use adjacent to waterways. Native species tend to be very sensitive to herbicides (including Roundup) so the areas need to be sprayed well before (ie, about two months before) planting.

- Herbicide should be used at recommended rates.
- Apply herbicide sufficiently in advance so that weeds and pasture are showing clear signs of death when planting takes place.

Pest control

New native seedlings on pasture land are favoured food for rabbits. Considerable plant damage can occur within one or two days of planting so effective animal pest control prior to planting is strongly recommended. The palatability of native species to each pest appears to vary from one region to another. Five-finger is the first plant sought out in the Bay of Plenty yet largely left in preference for kanuka in parts of the Waikato. Local knowledge can assist with the selection of less palatable species, and they can be heavily planted along fencelines from which rabbits and hares usually approach.

Pukeko can cause havoc amongst flax and sedge plantings, each bird often pulling as many as 100 or more plants in a night. The removal of the birds may be necessary in some areas, but the problem can also be overcome by planting larger plants (40 cm high seedlings or more).

5.6 Ongoing site maintenance

Native riparian plantings are often criticised because it is thought that they harbour and assist the passage and dispersal of pests and weeds. Continuous corridors of native trees and shrubs (corridors of any plants, for that matter) do serve as homes and corridors for possums and perhaps stoats and ferrets. However, the net environmental benefit to water quality and biodiversity is likely to well exceed these negative aspects. Rabbits and hares prefer open pastureland and are unlikely to use riparian corridors for passage.

Riparian plantings of any description can encourage the growth and dispersal of weeds, but this generally only occurs when trees and shrubs are poorly maintained, resulting in gaps in the plantings or where seedlings are planted at wide spacings. A commitment of time and resources to regular, ongoing site maintenance is vital if the native planting is to be successful.

5.6.1 Weed control

Regular (chemical) releasing of native seedlings from competition from grasses and weeds will be necessary for several years. If releasing is not undertaken, high plant mortality can be expected. On fertile soils and in warm summer climates the planting sites may need to be released between two to four times during the growing season, and this may need to be continued for three to four years after planting.

Using bamboo stakes to mark the position of seedlings can reduce the likelihood of seedlings being lost in long grass or weeds or for being inadvertently sprayed.

Photograph 13: Bamboo stakes are an effective way of marking the location of newly planted seedlings and of preventing the accidental spraying of seedlings when they become covered by weeds or long grass. The freshly positioned ponga logs on the slope have been placed there to stabilise the slope from erosion caused by the stream at its base (out of view). Freshly cut pongas are necessary to achieve a good survival rate. Once established the fibrous roots of the tree fern function well to repeal flood waters. Ponga survival can be improved by lying the logs down horizontally so that two-thirds of the trunk is buried in moist soil.

It is generally recommended that planted areas not be blanket sprayed to kill all vegetation between plants. The removal of pasture or less problematic weeds between seedlings can open up the site to occupation by invasive weed species which will ultimately be more difficult to control.

The need for weed control will diminish substantially as soon as the planted seedlings begin to form a canopy and shade the ground. Planting seedlings relatively close and replacing dead seedlings will enable weed exclusion to occur more rapidly.

5.6.2 Pest control

Ongoing rabbit and hare control will be necessary at least until the growing tips of the seedlings are well above bite height.

Possum control will be need to be continued indefinitely. Unfortunately, possum numbers (and so the need for their control) can be expected to increase as the restoration planting matures. Bait stations for possums and rabbits can be an effective, low cost method of maintaining pest control in a riparian area, but continuous use of poison baits will very quickly lead to bait shyness and ineffectual control. Poison baits should be applied in timed pulses; get expert advice (from a local pest control firm or regional council representative) for this.

There are several animal repellants which appear to function well as deterrents to rabbits and possums. These can be purchased through horticultural suppliers or stock and station agents.

As the bush area grows and matures, seed will begin to be produced and birds, insects and other animals will begin to arrive. The control of rats and mice (which eat seed, insects and bird eggs) and stoats, ferrets and cats (which eat eggs and birds) will greatly assist the health and vitality of the bush as habitat for plants and animals.

5.7 Cost

Native trees are expensive to plant and maintain compared to pines and other exotic timber species. If all work is done commercially, the cost of native plant establishment can range from $4.20 to $10.00 per plant at 1999 prices. A 40-cm seedling may cost between $1.20 and $3.50, depending on the container size and species. Site preparation and planting, if undertaken commercially, may cost between $1.50 and $2.50 per plant, and considerably more where extensive weed removal is necessary. Annual releasing of seedlings may range between $0.50 and $1.50 per plant depending on the rate of grass and weed growth and the nature of the land, and extended over three years will cost between $1.50 and $4.50.

These costs are substantially reduced if landowners plant and maintain their own native patches. Plant small areas at first and use the correct species and spacings, to minimise losses. Records from several restoration projects suggest that the long-term cost will be significantly lower and the likelihood of success greater where adequate time and resources (for recommended plant spacings and post-planting maintenance) are allocated to a restoration project in its initial years.

5.8 Flooding

The growth of trees and shrubs on stream banks is often cited (especially by engineers) as a cause of flooding. The argument is that plants slow the flow of water down and cause the backup of floods.

There is no doubt that the invasive willow and poplar species which tend to choke stream channels can play a significant role in magnifying floods. It is also important to realise that the major causes of increased flooding on farmland are:

- the extensive network of upstream surface and subsurface drainage channels
- the straightening of streams and rivers

- the drainage of wetlands
- the removal of upstream riparian vegetation and forest cover and, in more urbanised areas, the conversion of streams into concrete culverts.

Compared to these major causes, planting native riparian shrubs, groundcovers and small trees along stream banks is likely to contribute very little to increased flooding.

5.9 Intercepting agricultural contaminants

The most effective way to intercept and filter out contaminants from surface runoff and emerging groundwater is to use exotic grasses and native sedges and rushes on relatively level sites, sites over which surface runoff passes and groundwater emerges from the ground. Sedges and rushes are particularly effective for this:

- They typically form a dense cover over the ground, which slows down the passage of water.
- Their many fine leaves are ideal filters or sieves, reducing the velocity of water and encouraging the settling-out of solids (sediment with attached nutrients, and faecal material).
- They grow well-in saturated soils and can tolerate periods of immersion.
- They can tolerate and will grow through accumulated sediment.
- Many are tolerant of periods of dry.
- They are generally tolerant of both low and high fertility.
- They tend to accumulate organic matter and help create anaerobic conditions, which are important steps in lowering nitrogen levels.

Exotic grasses can be excellent filters, but they are not as tolerant of wet conditions.

Trees and shrubs are less well-equipped to intercept and filter out contaminants in surface waters because they do not provide the same leafy filter at ground level and because areas of trees and shrubs tend to shade out groundcover plants that could perform that function. There is some evidence, however, that thick layers of forest-floor organic matter can be quite effective as a contaminant filter. Trees and shrubs are also less likely to create conditions suitable for denitrification because of their inability to trap water for long enough periods and because trees can cause riparian areas to dry out.

Wet areas and filter strips are likely to be most effective in three locations:

- seepage zones (within the riparian area and outside it) and wetlands
- artificially created grass filter strips anywhere that is relatively level and intercepts surface runoff
- on the landward margin of riparian margin plantings.

5.9.1 Seepage zones and wetlands

These generally occur where groundwater emerges and are particularly valuable where they also lie in the path of surface runoff. To sustain the density and variety of wetland plants and to function effectively, particularly in terms of denitrification, these wet areas:

- must remain wet for all or most of the year. Most wet areas on farmlands have been previously drained and the effects of drainage will need to be reversed (removal, infilling or blockage of surface drains and subsurface drainage pipes) to improve their effectiveness.
- must be fenced off from farm livestock. Most sedges and rushes (including flax) are palatable to stock, and cattle can cause considerable damage to the water absorbing capacity of wetlands by trampling.
- should be large enough to absorb and slow down surface waters arriving during heavy rain. If the wetland is too small, it will become quickly saturated during heavy rain and inflowing water will pass across the surface of the wetland and exit in an unaltered (still contaminated) state.
- may require replenishment planting. Native sedges (*Carex* species), bullrushes (*Juncus* species) and flax (*Phormium* species) grow well in these environments and are easy and cheap to obtain and plant. All can be split by spade into several fans from a single parent plant in the field, and each fan can be planted separately.

Dense plantings, at about one metre spacings, are suggested for the sedges and rushes, whereas flax are better planted at 1.5–2 metre intervals.

5.9.2 Grass filters

Artificially created grass filters can be used anywhere on the farm to slow down the speed of surface runoff (see Photograph 14). They can be created temporarily across the face of a hill slope during winter to keep stock off a wet area or to reduce the velocity of runoff and likelihood of pugging damage down the slope. They have greatest value when they can be established on relatively level portions of valley or slope (benches and sills) where surface runoff is most likely to occur. In this position, dense long grass can dramatically slow runoff which will encourage the settling out of sediment and faecal particles. The grasses will tend to accumulate this sediment, releasing water downslope at a slower, less erosive speed and with a lower sediment content.

Exotic grasses, when left to grow long, perform this role as effectively as sedges and rushes with the added bonus that they can be grazed during the dry season and only need to be excluded from stock immediately prior to and during the wet season. Bullrushes often occur in surface drainage channels and seepage areas, and they should be encouraged where filter strips are to be maintained.

There is some evidence to suggest that such grass filters may work for a limited period only before they become unstable and release the accumulated sediment load in one catastrophic event. This would seem most likely to occur on steep slopes and during heavy rainstorms. Wetlands may also have a maximum storage capacity and may on occasions release their sediment load during heavy rain or storm events. While this may reduce the apparent effectiveness of grass and wetland filter strips, research suggests that the impact on the stream ecosystem of occasional catastrophic sediment (and nutrient) release is substantially less than moderate but frequent levels of contamination.

5.9.3 Filter strips (zone)

These strips function exactly as the grassy filters. They can either be created as ungrazed strips of grass within the fenced off riparian margin (between the fence and the stream bank, or as a strip between the fence and planted trees and shrubs), or they can be sedges and rushes planted in the same locations.

Filter strip width

Grass filter strips are sometimes unintentionally created where stock have been fenced out of stream channels. In these cases the grass strip is typically very narrow and probably has little effect as a sediment trap.

Wider, deliberately created grass filters probably do remove solids from surface runoff and are possibly most effective on flat land where fenced-off filter strips are more likely to intercept a greater percentage of runoff. The cumulative effect is greatest when all streams and drains are fenced off and have grass filter strips along their margins.

There is no one optimum filter strip width. The Department of Conservation/NIWA riparian guidelines (Collier et al, 1995) provide a formula for estimating the minimum filter width under varying conditions, although the general rule should be “the wider, the better”.

Photograph 14: “The wider the better.” This 10–15 metre wide filter strip of rank grass provides a very good buffer to surface runoff and to the impact of flooding (Waikakahi Stream, South Canterbury – see *Case Study 2*: Dairying and Border-Dyke Irrigation along the Waikakahi Stream: A water management challenge).

5.9.4 Weeds and grazing

Unmanaged grass filter strips have a tendency to be invaded by weeds, especially when the grasses have aged and are less dense. Blackberry, in particular, is quick to occupy and dominate unmanaged stream margins.

Occasional grazing can be used to manage the weeds on filter strips and maintain vigour and density in the grass growth. Grazing of stream-margin filter strips may be an acceptable management option on some sites, as long as:

- the grass is not grazed too low or too frequently
- the filter strip is not grazed during winter or the wet season
- the grass is given plenty of time to regrow before the wet season arrives
- cattle, especially adult cattle, are not used (because of the damage that can be done to stream banks and contaminants that can be passed into stream water)
- there is not a high risk of streambank erosion.

5.10 Ponds and flooding

Ponds or dams situated in depressions and valleys and areas where surface waters pass can serve as very effective sediment traps as well as being useful for stock water and as habitat for wildfowl and game birds. Care needs to be taken to ensure that the dam outflows are able to release excess water during heavy rain without causing erosion downstream.

The risk that flooding poses to permanent fencing is often given as a valid reason for not fencing off riparian margins. Battened fencing can suffer considerable damage when hit by flooding, and with the apparent increase in large floods in recent years some farmers (eg, in Northland and the Hawke's Bay) have been faced with repairing their fences three or four times a year. There are several well-tested methods of fence construction that can reduce flood damage and still be sheep-proof:

- build the portions of fence likely to be hit by flood waters without battens (posts can be placed a little closer together if necessary)
- place the wires on the side of the post away from the flood waters and use unbarbed staples, so that they pop under the weight of the flood waters (note that the wires are best positioned away from the stream where flood waters leave the stream channel, but may be better positioned on the stream side where flood waters re-enter the channel)
- where flood water regularly passes across the property in a flood channel, run a separate wire strain across the entrance and exit to the flood channel (if flood waters remove that part of the fence, the remaining areas of fence on either side do not go with it).

Photograph 15: Appropriately positioned ponds or lakes can serve many functions: they can trap sediment and nutrients, supply water, buffer against downstream flooding and erosion, provide habitat for wildfowl and fish, and enhance the aesthetics of an area.

5.11 Farm shelter and shade

With careful thought and planning, riparian trees can also serve as shelter and shade for farm livestock. Although little research appears to have been undertaken to verify this, anecdotal information suggests that well sheltered and shaded stock are less stressed and thus grow more wool or meat or produce more milk.

The provision of shade trees away from the stream margin has been found to significantly reduce the amount of time sheep and cattle choose to spend in or near the stream channel, and may, along with the provision of trough water, be a means of reducing stream contamination when the cost of fencing is prohibitive.

5.12 Production forestry in riparian zones

The growth and harvest of trees for timber can be compatible with riparian zone planting and retirement, although the timber trees alone are unlikely to have any significant role in intercepting surface runoff. They may, however, have some role in removing nitrogen from groundwater for their own growth.

Timber trees close to the stream margin may contribute shade and organic matter to streams, but perhaps their most important benefit is that they can ultimately provide some economic return to cover the costs of fencing, planting and the loss of productive land.

Tasmanian blackwood (*Acacia melanoxylon*) has been one of the more commonly planted timber trees in riparian margins. This species enjoys the greater fertility, more reliable water supply and generally more sheltered aspects of riparian zones, but loses some value as a timber tree because of its poor form when grown in narrow stands along stream margins. Blackwoods produce their best form when established in scrub or well-vegetated areas. In riparian zones the trees are more open to frost and the heat of the summer sun, particularly those at the edge of the planting, and this leads to the formation of multiple leaders and many lateral branches. Trees in this situation need to be form-pruned every year for the first seven or eight years to produce a high quality log.

Pinus radiata, macrocarpa (*Cupressus macrocarpa*), Mexican cypress (*Cupressus lusitanica*) and several eucalypt species can be successfully grown in riparian margins, but they have limited value in controlling bank erosion and they are best kept back from stream margins and banks.

Poplars (*Populus* species) are now receiving some recognition as a potential timber tree and increasing volumes are being harvested. Many new poplar varieties are now available which are not invasive, unlike some of their predecessors, and some varieties have been bred that are not especially palatable to possums (kawa is an example). They are cheap and easy to establish (they take readily from poles), and their fast growth and deep rooting habit means they are excellent at preventing bank erosion. Added to this, they are deciduous and thus less likely to shade out streambank grasses and sedges.

Some farmers have planted riparian timber stands at wide spacings to provide continued grass growth under the canopy. The grass can be a surface runoff filter and be available for grazing in the summertime.

Photograph 16: Retired riparian margins offer some opportunities for timber production. Poplars have been planted at wide spacings and pruned on this Southland property for future timber production and continued summertime sheep grazing.

The greatest threat to stream health comes when the trees are harvested. The following precautions should be observed:

- trees should neither be planted nor felled where they are likely to contribute to streambank erosion
- trees should be felled away from the stream
- avoid felling and extraction when the ground is wet and surface runoff is washing through the riparian area
- avoid felling and extraction during times of fish spawning.

The clear felling of all trees may alter the shade climate of the stream to such an extent that instream life is negatively affected. Consider the likely impact of harvest on the stream well before harvest and draw up plans to reduce the impact wherever possible. Options could include:

- leaving some trees standing nearest to the stream (the stability of the remaining trees needs to be evaluated if this is to work)
- planting alternative shade trees along the margin of the timber trees well before harvest time
- harvesting the riparian trees in blocks over several years so that the entire length of stream is not left unshaded all at once.

Riparian areas can be used for several other potentially productive pursuits, including firewood production, beehives and fruit and nut crops.

5.13 Cultural and aesthetic values

With careful planning, a creative mind and a good knowledge and appreciation of the land, water, trees and wildlife, many of the areas set aside for improved water management can add substantially to the aesthetic appeal and recreational value of the property.

Maori are keenly interested in enhancing and restoring the health and functioning of riparian areas. Resource managers and landowners, to understand the areas and resources that are of cultural significance, will need to consult with Maori. Wherever possible the active participation of tiaki should be encouraged.

Case Studies

Executive Summary

Crucial to any action towards waterway management on farms is information on what might be done and how well such action has worked already. This publication gives 16 case studies of how New Zealand waterway owners and managers are dealing with problems relating to riparian pollution and contamination.

1. Managing erosion and drought: drystock farming on the Huatoki Stream, Hawke's Bay. The study deals with faecal contamination from sheep and cattle farms on rolling to steep hill country in central Hawke's Bay. Soils are mainly silty loam, underlain by muddy siltstone. The stream is a tributary of the Porangahau River, which has high recreational use.

2. Dairying and border-dyke irrigation along the Waikakahi Stream: a water management challenge. The land is in South Canterbury and used to be sheep country; in the last ten years, the Waikikahi Flats have become dairy farms. The land was originally wetland and swamp, a flood channel for the Waitaki River.

3. Waipunahau (Lake Horowhenua): restoring the mauri. The lower North Island lake is heavily eutrophied and the water is undrinkable. The lake bed, margin and Hokio Stream (the outlet) are now owned by the Muaupoko's Lake Horowhenua Trust. The Trust has been instrumental in planting a first round of native plants and in establishing a native plant nursery which will also train Muaupoko young people in skills needed for future stages.

4. Whangamata Stream: riparian, stream and water quality changes over 24 years of retirement. The stream is on the northern edge of Lake Taupo and is a significant trout spawning stream. Before retirement it was heavily grazed, wide and shallow, and had eroding banks. Its 24-year history of rehabilitation is fully documented and is a valuable indication of what can be expected in current improvement initiatives.

5. Peat farming in the Waikato: striking a balance between production and the environment. For peat farming to work, there must be a balance between maintaining a water table low enough for production and high enough to minimise shrinkage and impact on adjacent wetlands. This study looks at two dairy farms which have addressed the problem.

6. Deer farming and riparian management in Southland. High sediment loads from deer-induced erosion can be a major cause of water contamination. The study looks at two deer farms: one long-established, and one comparatively new.

7. Whaingaroa Harbour Care: community initiative to restore a harbour and a fishery. Raglan locals established a society to address the deteriorating state of their harbour, which has a narrow exit to the sea and serves as a catchment for pastoral farming and plantation forestry. Much planting has been done, and many members of the wider community have changed their attitude towards riparian management.

8. Dairying on pumice: controlling erosion, willows and poplars. Much of the volcanic pumice soils in the Reporoa basin, between Taupo and Rotorua, have major erosion problems following conversion to pasture lands. The Torepatutahi Catchment Scheme is recommending major land use changes and an extensive soil conservation programme.

9. Orcharding and sustainable land and water management in Eves Valley, Nelson. Pesticides are an essential part of orcharding but can damage water quality in a variety of ways. ENZA has introduced a voluntary integrated fruit production programme, designed to meet international demands for food safety and environmental responsibility, and most orchardists are participating in this.

10. Riparian habitat restoration on the Mangahanene. The stream, on the northern side of Lake Karapiro, near Cambridge, drains pasture on which sheep, cattle and deer are farmed. The stream passes through erosion-prone alluvial pumice. The landowners intend to re-establish indigenous vegetation and restoring the riparian ecosystem to be as self-sustaining as possible.

11. Commercial forestry and riparian management: environmental management by self-regulation. The study looks at Weyerhaeuser New Zealand's management of production forest in Nelson and Marlborough. The company has an environmental management system for its own operation and is working with the Tasman District Council to assess such a system in relation to the aims of Resource Management Act.

12. Riparian management in peri-urban Auckland: lifestyle blocks and landcare initiatives. When there are a large number of landowners, riparian management may be difficult, as owners are driven by a variety of goals and issues. One individual property at the Kumeu River is examined; also profiled is a community-based landcare initiative in the Hays Creek catchment, which supplies Papakura.

13. Commercial vegetable growing in the Franklin District: the search for sustainability. The property grows onions, carrots and potatoes for Europe and Asia; the owners are keen to monitor sediment loss and nitrate contamination of groundwater while maintaining their production at competitive levels. The owners are participants in the Franklin Sustainability Project, which is coordinated by a wide variety of organisations having an interest in land management by commercial vegetable growers.

14. Sustainable land and water management in the Waitomo Valley: reducing erosion to save a cave. The remaining life of the Waitomo Glowworm Grotto is threatened by build-up of sediment. A multidisciplinary catchment management group was set up; after a slow start, the landcare concept was applied, involving property protection plans and Land Improvement Agreements over a 99-year period. More work than originally planned has already been done, owing to the enthusiasm of landowners.

15. Mangakahia River Valley Landcare: managing water and weeds in Northland. The catchment drains the area west of Whangarei, adjoining the Wairoa River, and is large by Northland standards. A river landcare group is confronting significant issues for the valley, which is half pastoral, and the other half either plantation forestry or podocarp forest and scrub. The Mangakahia River floods regularly and rapidly, carrying large amounts of silt. Farm stock have free access to its edge. Two individual farm properties are described.

16. The Upper Kaituna Catchment Control Scheme: has riparian retirement been successful? The scheme was designed for Lakes Rotorua and Rotoiti, and its results after 10 years are examined in detail. Sediment and phosphorus loads and streambank erosion have both decreased; nitrate and particulate nitrogen loads have increased. Future recommendations and expectations are given.

Making a Difference: Turning Words to Action and Action to Results

Most rural people are aware that our waterways aren't in the condition they used to be, and are irritated by the fact that they can no longer safely drink from the stream they used to as a kid. Many rural people realise that farming practices are contributing to the deteriorating state of our waterways, and that something should probably be done about it. Quite a percentage of rural people accept that they and their farms could be adding to the problem, and they would like to do something about it. Some, but not enough, are doing something about it. The important questions are why are more people not doing more, and what is required to turn words into action?

Too many human factors relating to *motivation*, *perception* and *information* are the reasons why intentions aren't translating to action. To be motivated, people must have an important enough reason or incentive to change the way they manage water. Many have a perception, or general misconception, of what sensible water management need entail. Also they lack information, ie, readily available practical and cost-effective options for management that will produce positive results.

Sixteen case studies follow which outline the experiences of rural New Zealanders when it comes to sustainable land and water management and riparian restoration. They cover the length and breadth of New Zealand and as many rural situations as is possible in 16 case studies. The challenge at the start of this project was to link the various experiences and practices together in a coherent fashion. As it has turned out, there are common messages and experiences coming out of all of the case studies, and some of these are summarised below.

Money

The most critical element of motivation towards things riparian is money, or in many cases, the lack of it. Irrespective of moral or philosophical support for sustainable farming practice, a shortage of cash, accompanied by the perception that riparian management is inevitably costly to the pocket and to farm productivity, is the overriding reason expressed for lack of action. Expensive nine-wire post and batten fencing at $8 to $10 a metre, and 10-metre wide grazing retirement strips along productive river terraces is the common view of good riparian practice. In many situations, this perception is being reinforced by publicity and practice; permanent riparian margin retirement is often marketed as the panacea of sustainable water management, the cure-all for all of our water quality problems. In reality, it is merely one of the many management options open to landowners; there are several alternatives that can make significant improvements to water quality at low, or no, net cost.

On the other hand, all of the most substantial and successful riparian projects have had ready access to money. The Upper Kaituna Scheme in the Bay of Plenty (see *Case Study 16*), the Lake Taupo and Reporoa Catchment Schemes (*Case Study 4* and *Case Study 8*) and the Waitomo Catchment Scheme (*Case Study 14*) are among the largest undertaken in New Zealand; they were also heavily funded by central government during the 1970s, 1980s and early 1990s. Participants agree that they would not have undertaken the retirement work if a large percentage of their costs had not been paid for. However, of even more interest, several of those participants acknowledge that with the benefit of hindsight they would now not hesitate in undertaking the work.

Farm productivity

There is a strong perception among landowners, and among many field advisers, that riparian and water quality management invariably must result in lost farm productivity, upfront costs with no likelihood of a return, and the creation of obstructions to farm management. This perception is a significant reason why more riparian management is not being undertaken, but there is increasing anecdotal information and experience available to suggest that farm productivity can, in fact, benefit directly from improved soil and water management practices. Livestock and pasture management practices which reduce erosion and surface runoff will provide production gains by the prevention of excessive pasture damage and soil and fertility loss, and at the same time, significantly reduce the contamination of our waterways.

Several farmers interviewed for the case studies have seen the on-farm benefits of changed practices and appropriate land retirement and are now continuing to pursue improvements as much for the benefit of their farms and farm management as for the positive environmental benefits (*Case Study 14* and *Case Study 16*). Their on-farm productivity has not fallen at all despite sizeable areas of riparian fencing and tree planting. They are now spending their operating capital on their better land that produces more for every extra dollar spent on it (*Case Study 14*).

Funding and technical assistance

Several regional councils offer significant levels of financial support for riparian works (see *Case Study 1*, *Case Study 8*, *Case Study 14* and *Case Study 16*), especially riparian retirement and planting, and most offer free technical assistance, some in the form of farm and environmental plans (*Case Study 16*).

Several landcare and community groups around the country have very effectively raised substantial amounts of money from a wide variety of sources to fund riparian works (*Case Study 3* and *Case Study 7*).

International markets

Discussions with farmers around New Zealand have revealed that many consider the increasing international demand for sustainably produced produce, accompanied with the belief that New Zealand's clean and green image is under threat by poor land management practices, is reason enough for the adoption of improved land and water management practices. Others, however, express scepticism as to whether there is any direct market evidence of such international demand.

In compiling material for this publication, several examples have arisen where international markets are demanding evidence of sustainable production from New Zealand producers. Two examples are discussed in *Case Study 9* and *Case Study 13*. A third example is now making an impact on New Zealand's prime lamb trade. Marks and Spencer (through New Zealand meat processors, Affco), large and renowned retailers in Europe, now offer a premium on lamb when the farmer can demonstrate sustainable farm management and production methods. A Code of Practice has been compiled and farms are audited annually by the Ministry of Agriculture and Forestry to ensure compliance.

In addition, some larger export organisations are taking the initiative and developing their own codes of practice to show the world they have the systems to ensure effective quality control (*Case Study 11*).

Expectations

Research for this publication has revealed that the expectations of many landowners may be somewhat misplaced when it comes to the speed of stream and waterway recovery following riparian retirement. In some cases at least, these false expectations may have arisen from information provided by regional council staff or other professional advisers.

Equally, there is evidence of situations where the riparian management advised or undertaken may not achieve the objectives set for the project. In particular, riparian areas retired and planted in a solid cover of native trees and shrubs may, on its own, have limited long-term ability to filter and strip water and surface runoff of nutrients.

These issues are well analysed in *Case Study 4* and *Case Study 16* where long-term research has revealed some interesting trends.

Innovation

In some New Zealand locations, combinations of certain farm management practices, soil types and water availability can elevate the threats to water quality to very high levels (*Case Study 2*, *Case Study 3*, *Case Study 5*, *Case Study 6* and *Case Study 13*). The development of management prescriptions to reduce the potential or actual impacts on water in these high risk situations requires a thorough knowledge of water processes, a detailed understanding of local conditions and farm practices, and a lot of innovation. Sustainable long-term solutions cannot be developed for these difficult scenarios without the contributions of all parties involved, and a lot of well monitored trial and error.

Information

Landowners frequently shy away from active water or riparian management because of misconceptions they hold, and often these misconceptions arise from the provision of inaccurate or incomplete information. Landowners talked to in the preparation of this publication repeatedly stated or asked:

- to be provided with information that enables them to understand how water contamination occurs, as opposed to just having remedial actions spoon fed to them
- to be active participants in the development of solutions and alternative management practices (*Case Study 16*)
- to have available a range of improved management options to suit a range of financial and farm management situations
- that positive results would only be achieved by consultation and a voluntary approach rather than by regulation (*Case Study 2*).

There are various mechanisms available to assist the better dissemination of information and collective development of ideas. These are discussed below.

Landcare groups

Landcare groups can take many different forms. They can be formally incorporated organisations formed and run entirely by members of the community to manage a community issue (*Case Study 7*); they can be a semi-formal collection of local enthusiasts who meet to deal with environmental problems and are guided by regional council field staff (*Case Study 8* and *Case Study 15*); they can be groups initiated by regional councils to address local issues (*Case Study 2, Case Study 12* and *Case Study 16*); or they can be casual, irregular farmer gatherings where all issues of farming and the environment are discussed (*Case Study 1*). Any one or any variation of these can function effectively as long as the initiative actively involves local landowners and they feel free to willingly participate.

New Zealand Landcare Trust

The New Zealand Landcare Trust was established in 1996 to encourage and facilitate sustainable land and water management throughout the country, particularly by promoting and coordinating landcare groups. The Trust is funded by the central government, and the Trust board has representation from seven groups: Federated Farmers of New Zealand (Inc.), Federation of Maori Authorities (Inc.), Federated Mountain Clubs of New Zealand (Inc.), Fish and Game New Zealand, Ecologic Foundation (the former Maruia Society), Royal Forest and Bird Protection Society of New Zealand (Inc.), Women's Division of Federated Farmers (Inc.).

New Zealand Landcare Trust has several regional coordinators scattered around New Zealand whose role it is to work with landcare and other rural groups, providing information, support and technical guidance where it is required. The Trust can be contacted through its main office in Canterbury: PO Box 16-269, Christchurch, phone (03) 349-2630; fax (03) 349-2640; e-mail: info@landcare.org.nz

Farm and environmental plans

In some regions, landcare groups have less of a focus and instead regional councils offer an advisory service directly to landowners. This is often offered in conjunction with funding support for riparian works (*Case Study 1*, *Case Study 6* and *Case Study 16*). The opportunity exists for the various agricultural industry groups to provide environmental management information and support to their members via their networks of field representatives but at this stage that is not happening as well as perhaps it could.

Water monitoring

Landowners are often not aware of the degree of deterioration of their local stream, but when they are shown water quality data their increase in interest can be rapid. Many regional councils carry out substantial water monitoring programmes but the recorded data is not always easily accessible nor easy for non-technicians to interpret.

Water quality data is essential if the doubting portion of the community are to be persuaded there is a problem. Equally, regular monitoring is becoming increasingly important as a measure of the success of restoration efforts. In some cases the recorded information is able to show substantial improvements (*Case Study 16*) and changes (*Case Study 4*) in stream condition; however, the timing and location of routine regional council readings is not always suitable to detect local changes resulting from riparian initiatives.

Landcare groups, in particular, should be encouraged to purchase and use a stream monitoring kit so that they can gain a picture of local water quality condition, and over time record any localised changes or improvements resulting from riparian management. Often, the mere process of learning what life actually exists in a stream can increase motivation substantially. In addition, monitoring can be an effective means of demonstrating the severity of impact of some management practices such as allowing cattle free access to streams. It is important, however, that the expectations of landowners and landcare groups for water quality improvement do not outstrip reality, and that alack of measurable changes in the short term do not become a reason for loss of interest.

Several easy-to-use stream monitoring kits now exist. Some, such as the Hills 2 Ocean (H_2O) kit (produced by the Hawke's Bay Regional Council and Napier City Council) and the Stream Sense Programme (produced by Environment Waikato) have been designed principally for primary and secondary school students. Others, such as the New Zealand Stream Health Monitoring and Assessment Kit (SHMAK), produced by NIWA and Federated Farmers, have been produced to meet the needs of landcare groups and rural landowners. AgResearch (Parminter and Tarbotton, 1997) has produced a Waterway Self-assessment Scale for rural landowners to assess for themselves the quality of the waterways on or near to their properties.

Ownership status and land protection

Land ownership and property rights have been identified as important land and water management issues by farmers and regional council staff alike. The retirement of riparian margins often brings with it the landowner perception that the rights of ownership will be compromised once the fence goes up. This appears to be especially so where the cost of fencing and planting has been substantially subsidised by outside agencies (*Case Study 16*); landowner commitment to maintenance work within the strip seems to fall away the smaller their own contribution to the capital works.

Several regional councils require the signing of a Land Improvement Agreement (LIA) over the retired area in return for funding assistance (*Case Study 8*, *Case Study 14* and *Case Study 16*). While this provides legal recognition of the protected status of the land and imposes a responsibility on the landowner to manage the site, the degree to which landowners take responsibility for the riparian margins is quite variable.

The Queen Elizabeth II National Trust (QEII) offers an alternative form of protection for areas of significant native bush or wildlife habitat. The Trust will provide funding for perimeter fencing to permanently protect important patches of native bush, and in return place an Open Space Covenant over the land, which is binding on all future owners. As for the LIAs, ownership remains with the landowner but there are specific restrictions, imposed by mutual agreement, on the use of the land to safeguard the health of the indigenous plant and animal life.

Regional councils and the Resource Management Act

The Resource Management Act 1991 (RMA) provides the legal setting for resource management in New Zealand, and so has direct relevance to riparian issues on rural land. The RMA, or perhaps more accurately the way it is enforced in some areas, is repeatedly identified by some rural landowners as a significant reason for their inaction in the areas of sustainable land and water management. It is important, therefore, that the RMA be used as a guide to acceptable land and water practices, not as the reason for them.

The purpose of the RMA is to:

> *promote the sustainable management of natural and physical resources.*

In the Act "sustainable management" means:

> *managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while –*
>
> - *sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
> - *safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
> - *avoiding, remedying or mitigating any adverse effects of activities on the environment.*

Regional councils, in particular, have a definite role under the RMA when it comes to riparian management. Their functions include soil conservation, the maintenance and enhancement of water quality, the control of contaminant discharges to land, air or water, and the control of weeds and pests on private land.

The policies and regulations set by regional councils are documented in regional plans. These, and district plans produced by district and city councils, should be consulted to establish what can and can't be done with and to water and waterways in the region.

The Ministry for the Environment has produced a document entitled *Your Guide to the Resource Management Act* (1999). This publication is a useful guide to the operation of the RMA for anyone interested in or affected by the Act. Some other publications are cited in this selection of case studies; a complete list of references is given in the first part of this publication, *Managing Waterways on Farms.*

Case Study 1: Managing erosion and drought: drystock farming on the Huatokitoki Stream, Hawke's Bay

Hamish McLean and James Hunter farm sheep and cattle on rolling to steep hill country in central Hawke's Bay. Their properties drain to the Huatokitoki Stream. Farm management typically needs to negotiate periods of summer drought and the resulting feed deficits, followed by winter periods when the soils become saturated and are prone to slumping and erosion. The stream floods periodically and aggressively as a result of heavy rain.

Hamish McLean farms 530 ha, carries 2000 ewes and 700–800 hoggets, and winters 250–300 cattle. Further upstream on land with wider river flats and of less steep contour, James Hunter farms 640 ha. He carries 1800 ewes, 1000 hoggets, 60 breeding cows, 200 two-year-old bulls, and 160 yearling bulls.

The Huatokitoki Stream is a tributary of the Porangahau River, and drains a 10,500 hectare hill-country catchment to the east of Waipukurau, Hawke's Bay.

The farm land is rolling to moderately steep hill country with river flats of varying width alongside the river. The soils are mostly silty loams underlain by muddy siltstones, with alluvial soils on the river flats, and they become very wet in winter and are prone to slumps and earthflows.

Rainfall ranges from 800–1250 mm through the catchment. Prolonged summer drought occurs frequently.

Drystock farms dominate the catchment, with most properties carrying both sheep and cattle.

The mouth of the Porangahau River is a site of high recreational usage, particularly in summer when it is widely used for fishing, jetboating, water skiing and swimming.

Understanding the problem

Water quality

Faecal contamination levels range from high to very high. Measured near the confluence of the Huatokitoki and the Taurekataitai River, contamination levels have exceeded levels suitable for drinking and safe recreational use in virtually every reading since 1994, and in recent times faecal contamination has well exceeded safe livestock drinking levels on many occasions. In a largely pastoral farmland catchment, with no significant towns or villages, the principal source of the faecal contamination is likely to be from farm livestock, with the inputs arising in two ways:

- Cattle with direct access to the stream are likely to be significant contributors of bacteria contained in dung and urine. This is often greatest during the summer when cattle seek waterways to cool their feet and trees to provide shade.

- Faecal material contained in surface runoff is likely to be the other major source of contamination. Occasional extremely high faecal contamination readings suggest that the highest levels may occur as a result of heavy rain following a prolonged dry period. Faeces accumulate on the pasture during the dry spell and are carried in high concentrations to the stream when the first rains arrive.

Suspended sediment levels vary considerably with season and flow but are generally high. While stock-induced streambank erosion is likely to be a source of sediment, the greatest source of sediment is probably from hillside slumping and sheet erosion when soils are saturated (in winter) and following heavy rain.

Nitrate nitrogen levels are well below maximum safe drinking levels but probably still sufficient (mean recording of 0.19 g/m^3 NO_3-N) to create nuisance aquatic weed growth. Stream nitrate readings are typically highest in winter months when nutrient uptake by instream vegetation and dentrification in riparian wetlands are at their lowest.

Phosphorus concentrations occasionally reach levels where instream plant growth can be accelerated. Total phosphorus levels (median: 0.073 g/m^3) are disproportionately higher than DRP concentrations, and are also generally higher in winter (reaching between 0.1 and 0.23 g/m^3). This, along with the fact that elevated instream phosphorus levels are closely correlated to increased suspended solid readings, suggests that most phosphorus loss from pastures is occurring during heavy rain events when phosphorus, bound to soil particles, is carried by surface runoff to the stream.

Water temperature is likely to exceed 20°C for considerable periods during the summer especially where the stream is not shaded by riparian vegetation and during very low flow periods.

Instream habitat

Lack of shade (and consequent high water temperatures) and moderately high sediment levels accompanied by periods of low, or no, flow mean that only those areas under a tree canopy are likely to accommodate invertebrate and fish species natural to the area. No monitoring information was available to verify the relative biological health of the stream. Invertebrate monitoring downstream in the Taurekataitai River, where there is greater waterflow all year round, shows a moderate level of biological health.

Riparian habitat

Much of the stream channel, especially in the lower reaches, is open and exposed to full sun, with little or no riparian vegetation. Further upstream there are significant pockets of remnant indigenous riparian bush with a surprising diversity of tree species. Most pockets of bush are not fenced from grazing, while others with temporary fencing are periodically grazed by stock. Few bush margin or understorey plants remain and the adult trees are in poor health because of possum damage in the canopy and livestock (especially cattle) damage at ground level.

Downstream the stream channel is narrow, with steep grass covered banks. Stock have free access to the streambed. Further upstream the banks are not so steep or large, but the stream channel is still narrow and stock have easy access to the water along much of its length. Where cattle have access, banks and margins show signs of erosion and pugging.

The stream often floods onto the river flats during winter; in the summer it can dry to a few stagnant pools.

Because of the high recreational use of downstream waters and the very poor state of the wider Porangahau River catchment (including the Huatokitoki Stream) the Hawke's Bay Regional Council has identified it as a priority catchment for riparian management effort.

Huatokitoki Stream Condition Score: Contaminant Loading and Habitat Condition

Bacteria: VERY HIGH
probably resulting from free access of stock (especially cattle) into the stream channel and from overland faecal wash with rain.

Nutrients: MODERATE to HIGH
due to phosphorus entering the stream attached to soil particles.

Sediment: HIGH
caused by streambank erosion during high flow, cattle pugging and eroding stream banks; and sediment resulting from hillside and gully erosion.

Aquatic habitat: POOR
because of high water temperatures, lack of streamside vegetation and moderately high sediment loadings.

Riparian habitat: DETERIORATING
because of damage to existing trees caused by livestock and possums, and consumption of regenerating seedlings by livestock.

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

Managing the problem

Land use and management issues and constraints

Farm management constraints

Stock have required access to the stream to obtain water; however, both properties have reticulated water systems which can (and are) being extended to streamside paddocks.

One neighbour across the stream from Hamish McLean's property does not have access to a reticulated water system and currently must retain access for his stock to the stream water. This situation will clearly limit the impact of any riparian retirement undertaken by Hamish because only one side of the stream will be managed.

Flooding is a regular concern occurring several times in a year. Any permanent fencing constructed along the stream margin would be damaged and require repair after each flood and for this reason both farmers have been reluctant to construct permanent retirement fencing over flood channels. Added to this is the complication that the Hawke's Bay Regional Council will only currently provide financial assistance for riparian fencing constructed of permanent materials (eight- or nine-wire, post and battens).

Hillside erosion is a significant source of sediment (and probably phosphate) to the stream system. Management of the source and cause of the erosion is likely to have a significant positive impact on instream water quality.

Management priorities

Riparian and land management in the Huatokitoki catchment should target substantially reducing faecal inputs to the stream, by:

- excluding cattle from the stream
- creating grass filters to intercept surface runoff containing faecal material.

As well, such management should aim to reduce soil loss arising from erosion, by:

- excluding cattle from stream banks
- stabilising hillside erosion with tree plantings
- more sensitive winter grazing management
- developing sediment traps and grass filters to slow down the speed of surface waterflow and trap sediment
- protecting remnant stands of native vegetation from further damage from livestock, by:
  - permanently fencing all stock from native patches
  - controlling weeds (for the first 3–4 years) and pests (rabbits, possums and rats).

Financial assistance available

The Hawke's Bay Regional Council provides a comprehensive landcare package to landowners in the region and considerable financial assistance is offered:

- 50 percent grant (ie, contribution of 50 percent of all costs) for soil conservation (ie, soil erosion control)
- 90 percent grant for riparian margin protection in priority catchments only (the Huatokitoki Stream occurs within the priority Porangahau River catchment). Permanent fencing materials only are currently subsidised.
- 50 percent grant for native bush protection, with the requirement that the area must be covenanted either by QEII or the Department of Conservation.

Current management practices

James Hunter

James Hunter has embarked upon a sizeable riparian zone retirement project where both sides of the stream running through his property have been fenced off permanently from stock and the retired area will be systematically revegetated in native trees and shrubs.

Good management practices being undertaken by James Hunter include:

- A minimum riparian margin of 5 metres has been created on each side of the stream, allowing plenty of room for the establishment of a vegetation belt. This fencing and subsequent planting will reduce bank erosion, improve instream habitat by providing shade and leaf litter for food, and restore the remnant pockets of native riparian vegetation that will be linked by the new plantings and protected by the fencing. This riparian zone will <u>not</u> greatly reduce the volume of contaminants entering the stream because most of the water entering the stream will arrive in side streams rather than as diffuse overland flow.
- The eight-wire fences have been constructed with a single electric wire along the top to prevent cattle leaning over and eating the tops out of the growing natives, and the fences have been built without battens and with the wires on the side of the post away from the stream so that flood waters do not destroy the fence.
- A large pond (small lake) has been created at the base of one of the valleys that feeds into the stream. This long narrow pond serves as a wildfowl habitat (and a place for duck shooting) and as a stock water source, but most importantly the pond is strategically placed to trap sediment, nutrients and faeces washing off the surrounding slopes. The quality of the water leaving the pond and running to the stream is likely to be considerably improved on that arriving at the pond. The storage provided by the pond during floods could also be expected to reduce peak streamflows and so reduce downstream bank erosion.
- Upstream of the large pond, a long, gently sloping marshy valley bottom and adjacent regenerating kanuka face have also been fenced off from livestock. Water flows slowly along the marshy valley bottom and the encouragement of sedges, bullrushes and rank grass, in the absence of livestock, will create a very effective water filter. The ungrazed grasses will slow waterflow down in heavy rain reducing the intensity of flooding downstream; because the water will be travelling more slowly sediment (with phosphate attached) and faeces will tend to filter out and not enter the main stream in the concentrations that would be expected from grazed grasslands; and during periods of normal flow water should pool in places sufficient for denitrification (the conversion of nitrate to atmospheric nitrogen) to take place.
- The inclusion of the kanuka dominant face of regenerating native vegetation in the fenced off area will greatly increase the diversity of native plants and animals that will occupy this area.
- Hybrid willows and poplars have been planted to anchor hillside and gully erosion around the property.

Additional management suggestions:

- Control rabbits and possums around the areas to be planted.
- Include, within the retirement planting, more of the remnant native trees occurring naturally along the riparian zone.

Cost-benefit analysis

Costs

On the surface the work undertaken by James Hunter appears to be particularly costly, with several kilometres of eight-wire fencing (at $8–$10 per lineal metre) and the retirement of several hectares of land. However, with the funding assistance from the Hawke's Bay Regional Council the actual costs are considerably reduced. Ninety percent of the cost of riparian fencing and planting is being subsidised, as is 50 percent of the cost of fencing and retiring the regenerating kanuka bush and wet flats. In addition, 50 percent of the cost of poplar and willow pole plantings carried out to stabilise slips and erosion-prone areas has also been provided by the Hawke's Bay Regional Council.

James will face some additional, ongoing costs as a result of the retirement fencing and revegetation work. Planted native seedlings will need spray releasing from weed competition for several years and both adult trees and seedlings will benefit from possum and rabbit control.

Farm productivity benefits

Although James has lost several hectares from productive use, farm productivity or profitability is likely to have been improved in several ways:

- Stock now have access only to clean trough water supplies. Anecdotal evidence suggests that livestock drink more water when it is of high quality, and when they drink more they eat more.
- Poplar and willow plantings have stabilised eroding ground and dried out previously very wet areas reducing topsoil and fertiliser loss from pastures and making the pasture on these wet areas more accessible with less damage from pugging for longer periods of the year.
- The retirement of wet valley bottoms and stream banks will reduce the damage caused by the mud-hole creating habits of bulls and reduce the consequent pasture and soil damage caused by that behaviour.
- Erosion control and riparian margin tree plantings will increase shade and shelter for livestock.
- Stock movement (including the time spent moving stock) is likely to be improved by the removal of stock from wet, steep and less accessible areas.

Environmental benefits

- The quality of water entering the Huatokitoki Stream, derived from James' property, will be of substantially higher quality than was previously the case. Sediment, nutrient and bacterial content will be much reduced.
- The protection of existing riparian bush remnants and the planting of the riparian margins with natives should substantially improve the quality of instream habitat by providing shade (and lower water temperatures) and food sources for instream life. The restoration of the riparian zone vegetation will also improve terrestrial biodiversity by providing food and habitat for many plants and animals and a migration corridor for native birds.

Aesthetic and recreational benefits

- The overall appearance of the property is likely to improve considerably as the native plantings and retired bush areas grow and as native birdlife occupy the new habitat.
- The large pond is already a favoured area for waterfowl and offers duckshooting as a recreational pursuit.
- The poplar and willow plantings along with the regenerating kanuka block will provide variety to landscape that is rather short on trees in this part of the Hawke's Bay.

Hamish McLean

Hamish McLean's property is generally steeper than James Hunter's, with narrower alluvial flats adjacent to the stream. Slip erosion has been identified as a prime concern for farm productivity and recognised as having a significant impact on water quality. Sheep and cattle retain access to the stream water along some portions of the stream. There has been a reluctance to fence off all of the stream margins with permanent fencing materials because of the damage likely to be caused to fences during the regular flood events that occur in this valley.

Hamish has undertaken the following management practices, which will have a positive impact on water and riparian habitat quality:

- substantial willow and poplar pole plantings to stabilise erosion-prone slopes, gullies and earthflows
- retirement of erosion prone gully systems and planting with willows in the wettest zones and pines on the flanks. The pines and willows stabilise the soil against erosion while the rank grass serves to slow down the speed of water flow, thereby reducing its erosive force, and acting to filter out sediment and faeces washing off the slopes
- temporary electric fencing along some of his stream margins. Light grazing to control weed growth occurs behind these fences on occasions during the summer.

Suggested additional management options that could further improve stream condition:

- Supply trough water to the remaining few streamside paddocks that don't already have it.
- Permanently exclude cattle from the stream water and stream banks. While occasional light grazing within the fenced off areas is an acceptable practice to control weeds, cattle should be excluded from access to the water and erosion-prone banks.

- Retire substantial groves of riparian vegetation permanently. Cattle, in particular, are causing substantial damage to the roots and trunks of the cabbage trees, totara, matai and kowhai, and both sheep and cattle are consuming all natural regeneration under the canopy. Complete exclusion of all stock is the only way to encourage natural regeneration.
- Use temporary fencing across flood channels where flood waters leave and enter the stream channel to reduce the likelihood of flood damage to fencelines and use permanent materials for the remainder of the retirement fencing.
- Possum, rabbit and rat control will greatly assist the natural regeneration of native seedlings under the retired bush areas.
- Temporary fencing of wet flats, boggy areas and spring heads during the winter will exclude cattle. This will prevent pugging and contamination of water with sediment (and attached phosphate), urine and faeces. If these wet areas are retired in autumn a reasonable bank of long grass will establish and serve as an effective filter through the wettest winter months when surface water flow is at its greatest. Once soil conditions dry out in spring the temporary fencing can be removed and the accumulated grass can be grazed by stock.
- Sections of the stream running through Hamish's property are being choked by willows and these will be accentuating the effects of floods during heavy rain. Where possible these should be cut out and any regeneration controlled. Replacement planting with native trees and shrubs would complement the existing native bush areas and prevent future weed reinvasion.
- Encourage the neighbour across the stream to fence off his stream margins. At present the need to utilise the stream as a water supply prevents the neighbour from doing so. However, as a result of on-the-ground discussions the Hawke's Bay Regional Council has offered to provide financial assistance so that water can be pumped from the stream to supply paddocks adjacent to the stream.

Cost-benefit analysis

Costs

Fifty percent of the cost of all of the slope stabilisation willow and poplar plantings have been paid for by the Hawke's Bay Regional Council. This subsidy covers the cost of the poles, their transport to the site, the cost of planting and the cost of pest protection sleeves.

Temporary electric fencing of riparian margins is not currently subsidised by the Regional Council, so the areas of fencing that must cross flood channels will be built at Hamish's cost. However, all other riparian margins that can be permanently fenced will receive funding to cover 90 percent of the cost. Hamish will need to install water troughs and piping in paddocks adjacent to the stream at his own cost.

Because the remnant native bush areas are quite substantial and diverse, natural regeneration will occur once stock are permanently removed. Hamish will have to carry out rat, rabbit and possum control to assist this process. Weed control will also be necessary for some time until the natives become established.

Farm productivity benefits

- Poplar and willow plantings have stabilised eroding ground and dried out previously very wet areas reducing topsoil and fertiliser loss from pastures and making the pasture on these wet areas more accessible with less damage from pugging for longer periods of the year.
- Retirement of steep faces and eroding gullies and planting of the faces in pine trees will improve the profitability of such pockets of land in the long term.
- Once stock have access to clean trough water some improvement in stock health and weight gains may be possible.
- The willow and poplar plantings provide excellent summer shade and the pines and fenced-off native patches will provide useful shelter in winter.
- Stock movement (including the time spent moving stock) is likely to be improved by the removal of stock from wet, steep and less accessible areas.

Environmental benefits

- The stabilisation of eroding slips and earthflows will greatly reduce sediment reaching and contaminating the stream.
- The rank grass swards established in the retired gullies will effectively reduce the erosive force of water flowing off the hill and act to filter out sediment, phosphate and faeces before they reach and contaminate the stream.
- Permanent retirement of the native bush remnants will enable them to regenerate naturally. Because there is a good diversity of species still present in the canopy a diversity of bird life will bring in seeds of other native species from further afield.
- Maintenance and enhancement of the riparian vegetation remnants will maintain and improve their shading and food providing attributes to the benefit of instream plants and animals.
- Removal of stock, especially cattle, from the stream channel will reduce streambank erosion and fouling of the water especially during summer when cattle occupy the stream to drink and cool their feet.
- Once regeneration occurs the fenced off bush margins will filter out some of the nutrients, sediment and faecal material occurring in sheet runoff.

Aesthetic benefits

- The enhanced native bush areas will attract native birds to the area.
- The pine, poplar and willow plantings on the hill will enhance a landscape which has been largely without trees.

Motivation

Even with the financial assistance of the regional council, both James and Hamish have expended considerable personal effort and capital to improve their land and water management practices. Their motivation has been a wish to improve the long-term sustainability of their properties, both from a productive and an environmental point of view.

Case Study 2: Dairying and border-dyke irrigation along the Waikakahi Stream: a water management challenge

Prior to European settlement the land surrounding the Waikakahi Stream was a periodically active flood channel for the adjacent Waitaki River in South Canterbury. The landscape would have been scattered with swamps and wetlands and dominated by flax, raupo, sedges, rushes, ferns and indigenous grasses. The cabbage tree is likely to have been a predominant tree in the area. Sedges (tussock-like grasses) would have lined the stream course and, because the stream is spring fed, the water would have been clear, clean and of a constant temperature. The stream waters, which flowed over a clean, stony bottom, abounded in freshwater mussels (“kaakahi”, hence the stream’s name), freshwater crayfish (koura) and eels, and the rich abundance of plant and insect life provided food and habitat for as many as 42 native bird species.

Today, little remains of the original vegetation on the flood plain or along the stream margin and only 24 of the native bird species present in the mid-1800s remain. In their place agricultural pastureland predominates and the once numerous wetlands have been drained.

Sheep farming has been the predominant land use over the past 100 years, although dairy farming occupied some of the land during the late 1940s and 1950s. Dairy farming now occupies virtually the entire Waikakahi flats. A flood irrigation scheme (now referred to as the Redcliff scheme), drawing water from the Waitaki River, was built by shovel and barrow during the 1930s. Since that time livestock farming has relied heavily on the availability of irrigation water to maintain profitability in an area prone to summer drought, and lying on porous river gravels. The annual rainfall in this area of South Canterbury periodically falls as low as 330 mm. A more modern and efficient border-dyke irrigation system was constructed in the 1970s, and this enabled the existing sheep and beef farmers to increase productivity considerably and include some mixed cropping. Irrigation was restricted then to five-eighths (63 percent) of any property.

A decline in returns from sheep farming and the consequent availability of “cheap” land, an upswing in the profitability of dairy farming, and the availability of irrigation water, lead to a dramatic change in land use only seven to eight years ago. The Waikakahi flats have now been almost entirely converted to dairy farms, many of them owned and managed by North Island dairy farmers who moved south in search of cheaper land. Irrigation is now permitted over 100 percent of each property.

Water monitoring undertaken since 1995 has shown that the quality of the Waikakahi waters is poor (see detail on following pages), and little remains of any natural riparian vegetation. There is no recorded historical information available to show when the riparian vegetation was removed, nor is there any documented evidence to show when the deterioration occurred and what impact increased use of irrigation water, increased stocking rates and changing land use has had on stream water quality since the 1930s.

Local opinion varies considerably. Some believe water quality has largely deteriorated since the arrival of intensive dairy farming in the last seven to eight years and suggest that the stream’s fishery has collapsed recently because of this. Others believe there were signs of poor water quality well before the recent arrival of intensive dairying. It would seem that most of the original riparian vegetation was removed prior to 1950, including the wetland vegetation that would have occurred on the heavier soils surrounding the springs in the upper reaches of the stream.

Chris Paul is one of those farmers who migrated south in search of cheaper dairy farm land, arriving in 1994 from Reporoa in the central North Island. He now farms 285 ha alongside the Waikakahi Stream and is active in the Waikakahi Stream Resource Care Group, a group of local farmers keen to reduce the impacts of dairying on the stream and riparian habitat.

The Waikakahi Stream is fed predominantly by spring water arising near State Highway 82. It flows through farmland (effectively the old river terrace of the Waitaki River) for approximately 25 km before discharging into the Waitaki River just upstream from the State Highway 1 bridge adjacent to the small South Canterbury town, Glenavy. Several small ephemeral streams (ie, they only flow periodically) supply runoff from the hills to the west to the Waikakahi during winter and with heavy rain. Because the stream is spring-fed, it has a consistent natural year-round flow. Only during heavy rains when runoff from the surrounding hills is significant does flooding occur. The Waikakahi runs across flat or near flat land for its entire length. As a consequence water flow is not rapid.

According to local experience serious flooding does occur on occasions. The stream channel is not incised to any extent and when heavy rain creates significant runoff from the adjacent hills flood waters tend to escape the stream channel quickly and find alternative courses over farmland. As well as causing obvious damage to fences and pastures, this situation is likely to result in the stream channel being less well flushed with each flood than would be expected in a more entrenched channel. The consequences of this need to be considered when restoration targets are established and expectations for water quality improvement set.

Understanding the problem

Water quality

Three years of monitoring reveal the severity of the Waikakahi Stream water quality problem.I It is important to acknowledge that the condition of this stream is not dissimilar to streams in other intensively farmed areas of New Zealand.

Faecal contamination

Faecal coliform bacterial counts show a routine high level of contamination that makes the stream totally unsuitable for any contact recreation (ie, above 200/100 ml), well in excess of drinkable levels, and frequently unsuitable as a stock water source (above 1000/100 ml). There are several potential causes of this contamination:

- point-source pollution from cow sheds
- directly from cattle with free access to the stream
- transportation of faecal material in surface irrigation runoff and runoff resulting from rain.

Bacterial readings are not sufficiently high to suggest that point-source discharges are a major source of contamination on the Waikakahi.

Some farms are yet to fence off their riparian margins along the stream and some still run their cows periodically through the stream for milking, but this alone is unlikely to account for the continuously high faecal levels in the stream water.

In each of the 3½ years of monitoring, the highest faecal coliform levels have occurred in the period October to December when the milk production season is benefiting from maximum pasture growth (also maximum consumption and nutrient recycling) and when the irrigation is used for the first time in the season. Coliform levels fall off noticeably through the rest of the production season coinciding with reduced grass growth and consumption and increased irrigation (increasing the dilution factor). This evidence would suggest that the most significant source of faecal contamination in the Waikakahi is from faeces carried directly to the stream in irrigation bywash.

Nutrient contamination

Nitrogen

Nitrate nitrogen levels in the stream water are routinely high to very high (range: 0.5–2.3 g/m^3 NO_3-N) through 12 months of the year. The sources of this excess nitrate could be from applied nitrogen fertiliser, nitrogen arising from spray deposition of effluent, and from dung and urine, and is most likely to reach the stream by leaching directly to the groundwater. Urine is likely to be the predominant source of nitrate on a flat, intensively farmed, irrigated livestock area such as the Waikakahi.

Much of the farmland surrounding the Waikakahi lies on porous river gravels, and because of this it is likely that shallow groundwaters and the water contained in the stream channel mix relatively freely. No nitrate measurements have been taken from the springs feeding the stream so background nitrate levels cannot be determined.

Phosphorus

Unusually high levels of soluble phosphorus (in excess of 0.5 g/m^3 DRP) were detected during the summers of 1996 and 1998. This is most likely to be caused by the washing of fertiliser from paddocks in irrigation water. Phosphorus is most prone to transport in solution immediately after the application of fertiliser; it otherwise tends to bind to soil particles and in this form is lost from soil in surface runoff.

Sediment

There have been periodic late autumn/winter surges in stream sediment levels in each of the last three years of monitoring. The cause of these sediment peaks is somewhat of a mystery to farmers and technicians in the area. Drain clearance works have been suggested as the likely cause in 1997 but the source of the repeated peak in 1998 is less clear. Pugging of stream and drain banks by cattle is another possibility, but many farmers graze their stock away from the area during winter reducing the likelihood of bank erosion and pugging as a significant source of sediment.

There are few obvious sources of sediment on the dairy farmland to explain the winter high sediment load. Dense, healthy pastures lying on flat terrain are not likely to generate high sediment loads, the stream is not entrenched and the banks not unstable, and much of the stream is now fenced from cattle. However, the combination of three important factors could explain the high winter sediment concentrations:

1. The shallow gradient and slow flow of the Waikakahi stream means it has accumulated within its channel substantial quantities of sediment over the decades of agricultural development. These would be mobilised during winter stream clearance and rainfall induced runoff.
2. The stream is at its lowest baseflow level during the winter months, often at half the flow of summer months when irrigation water supplements spring water.
3. Runoff from the adjacent hill catchment is most likely to occur during the winter when the soils there are saturated. Sediment is likely to be carried in this runoff.

Sediment derived from winter hill-country runoff, supplemented by high existing stream channel sediment deposits (at least when they are mobilised during stream freshes) and imposed on a stream with half its summer flow could be expected to elevate winter turbidity and sediment concentrations well above summer levels.

Waikakahi Stream Condition Score: Contaminant Loading and Habitat Condition

Bacteria: VERY HIGH
resulting from overland wash from irrigation and heavy rain and from cattle with direct access to the stream.

Nutrients: VERY HIGH
due to periodically high phosphorus inputs from irrigation out-wash, high irrigation-induced leaching of nitrogen to groundwater, and some N and P inputs from cattle with free access to the stream.

Sediment: HIGH
periodically high concentrations possibly originating from surrounding hill country and more evident in winter due to substantially lower baseline flow.

Aquatic habitat: POOR
because of the turbid waters, increased (and accumulated) sediment loads and excessive weed growth (due to the high nutrient and sediment levels).

Riparian habitat: POOR
little remains of a once diverse natural ecosystem.

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment: irrigation water

High stream flows and groundwater levels occur in the summer, and low flows and groundwater in the winter. Over 75 percent of the summer flow is likely to be due to direct and indirect flows of irrigation water. While the very high summer water table in itself is not likely to influence water quality, the large volume of irrigation water that leaches through the soil to create the elevated water table is a significant source of nitrate concentration to groundwater. Peak irrigation coincides with peak applications of fertiliser and effluent, further elevating groundwater nitrate levels. The free mixing of stream water and groundwater through the porous gravels means that stream nitrate concentrations are likely to be closely related to concentrations found in the shallow groundwater.

Instream habitat

There appears to be no documented information available that records the state of the instream flora and fauna prior to 1990. Local opinion is that the fishery has declined substantially over recent decades, although views are divided as to how recently the decline has occurred. Freshwater mussels and crayfish have apparently disappeared from the stream probably because of increased sedimentation and increased weed growth. For the same reasons, invertebrate life is likely to have altered with an increase in species tolerant of high sediment loadings and aquatic plant growth.

Riparian habitat

Very little of the original riparian and wetland vegetation remains, and because of this the diversity of indigenous plant and animal species has declined. Three areas of remnant wetland remain in the vicinity of the headwater springs and these are worthy of protection.

Managing the problem

Land use and management issues and constraints

The effects of border-dyke irrigation

While there is some question as to the state of the Waikakahi prior to dairy farming, there is little doubt that dairying is now contributing significantly to the continued poor water quality status of the stream. The more intensive nature of dairy farming with high rates of nitrogenous fertiliser application and high stocking rates increases the nutrient and pathogen concentrations on and in the soil and increases the likelihood that some of it will reach groundwater and stream water. However, it is the application of large volumes of irrigation water onto well fertilised soils which has increased the level of stream contamination to very high levels in the Waikakahi. This has been occurring in several ways:

- Border-dyke irrigation operates by flooding the paddocks with water. This system requires the use of large volumes of water to achieve an effective pasture coverage. The upper portion of each irrigation bay receives substantially more water than it needs so that the lower portions receive sufficient coverage. The excess water inevitably leaches through the soil to the groundwater, elevating the water table and carrying nitrate (from dung, urine and fertiliser) with it.
- The high summertime water table, and porous gravel substrate, means that contaminated groundwater mixes freely with stream water, effectively creating one large subterranean river across the width of the Waikakahi flats. This is particularly significant to stream water quality management because any contaminants that leach through the soil can be expected to find their way quickly to stream waters.

- The excess irrigation water that often collects at the end of each paddock either pools and soaks to groundwater or, in the past at least, has been deliberately drained into the Waikakahi Stream.
- Border-dyke irrigation creates substantial surface flow so that dung, sediment and even fertiliser particles are likely to be carried in suspension and will flow with the excess irrigation wash into the stream where this is allowed to occur.
- Some paddocks remain along the Waikakahi that have not been recontoured using laser technology. Uneven contouring results in more water having to be applied to cover humps with the result that more leaching is likely to occur and more surface runoff to the stream could eventuate.

The availability of abundant irrigation water is necessary, in the eyes of local farmers, in order to sustain farming of any type along the flats beside the Waikakahi, and is essential if dairy farming is to be contemplated. Without the water, dairy production would not be viable on the drought-prone soils. Border-dyke irrigation is (once installed) a low cost system to operate and water drawn from the Waitaki River for the Waikakahi scheme is never in short supply. At the same time, the large volumes of water being applied to well fertilised soils and the ability of irrigation out-wash to flow directly into the stream are contributing significantly to the maintenance of poor stream health.

It is quite conceivable that if the Waikakahi flats had remained in sheep and beef farms that the water quality problem would be much the same as it is today under dairying. Dairy cattle are not in themselves any more of a threat to water quality than sheep or beef cattle (except perhaps where stock have free access to streams in which case sheep may have less impact than dairy and beef cattle – see Section 4.4.2). It is the intensity of farm practice that elevates the risk of water contamination. Irrigated and fertilised pastures grow more grass and so can carry more livestock, and the additional livestock in turn generate more dung and urine.

If intensive farming is to remain a viable land use in this area <u>and</u> the health of the stream is to be improved, irrigation water needs to be utilised more efficiently and managed more carefully. Management practices to achieve this are discussed below. Spray irrigation, particularly systems which lie close to the ground and have multiple spray heads, can reduce the likelihood of surface runoff and utilise water more efficiently than flood irrigation. Spray irrigation systems can be less expensive to purchase and set up but are generally more labour intensive, and expensive, to operate.

Some Waikakahi farmers use spray systems to irrigate some of their pastures, but on much of the land in this area their comparative efficiency is questionable. In windy conditions, up to 50 percent of water droplets released from spray nozzles never reach the area of pasture targeted. The Waikakahi flats are particularly windy and, in addition, evaporation of water falling directly onto sunbaked stones commonly found on the gravelly paddocks can greatly reduce application efficiency. When potential water efficiency of spray systems is weighed against the site conditions and the superior energy efficiency of flood irrigation, spray irrigation on the Waikakahi may not provide a suitable alternative option.

Riparian retirement and planting

All but a few farmers have fenced off their riparian margins, but opinions vary as to the benefits of permanent retirement. Notable concerns include:

- retired pasture areas are likely to become weed infested if not periodically grazed
- prolific in-stream weed growth quickly chokes the stream and induces flooding when cattle are no longer able to graze the weed
- if grazing is not permitted in retired areas who will pay for the cost of mechanical or chemical weed control?

Concerns have also been expressed about the value of planting trees and shrubs, especially natives, in the retired zone:

- native tree, shrub and flax/sedge plantings are likely to encourage and harbour animal pests such as possums and stoats
- tree plantings can induce flooding by occupying channel space and preventing flood water re-entering the stream.

Stock access to drains and headraces

Most properties that have fenced their stream margins have left drains and headraces open to stock. Weed management and the loss of important pasture have been expressed by farmers as important reasons why headraces should not be fenced. However, where cattle do utilise them as a source of water and to cool their feet, especially during the heat of summer, direct deposition of dung and urine into drains can be significant sources of contamination. Unfenced drains that feed directly to the stream are likely to provide the most concentrated sources of contamination.

Subsurface drainage

The upper portion of the Waikakahi lies on heavier swamp soils. Much of this land has had subsurface drainage installed. These drains, which either drain directly to the stream or to open drains, are likely to be significant sources of contaminants to the stream. Subsurface drains collect leached nitrate from the soil and tend to channel sediment and attached phosphorus as well. Unless the drains emerge to the surface prior to entering the stream, contamination from this source is unmanageable.

Current land and water management practices: Waikakahi Resource Care Group

In response to complaints laid by recreational users and the general public about the deteriorating quality of the Waikakahi Stream, the Waikakahi Resource Care Group comprising local farmers was formed in 1996 under the guidance of the Canterbury Regional Council. Stream monitoring over several years and an ecological assessment (both carried out by the Regional Council) highlighted the extent of the problem and a course of action was proposed to improve the health of the stream. The Regional Council set up two demonstration sites, one to show the improvements to be gained by retirement fencing and enhancement planting, the other to demonstrate the use of bunding to control the direct runoff of irrigation water to the stream. Guidelines for cleaning streams and drains were produced and a two-phase stream protection and enhancement programme was written. A workshop to discuss stream management issues was held in 1998 and a course of action agreed to:

1. Streams and drains would be cleaned of silt and weed where appropriate.
2. Stock troughs would be installed in all remaining paddocks to avoid direct access of stock to streams for drinking-water.
3. The Council would assist individuals wanting to pursue stream enhancement options identified in the ecological study.
4. Another meeting would be held in six months to discuss progress.

Riparian margin fencing and bunding to prevent direct flow of irrigation wash to the stream were seen as the two actions most likely to have an immediate effect, and designs for portable concrete bridges have also been discussed.

There was strong agreement that positive results would be achieved by consultation and a voluntary approach rather than by regulation.

Fencing, bunding and planting have been undertaken by many of the farmers along the stream since that initial workshop, and the Council monitoring programme continues to record any changes in stream water quality, although there is increasing realisation that improvements will not occur rapidly. Considerable effort continues to be put into improving the contours of each paddock so that watering times and therefore water volumes are reduced, and farmers are giving increased thought to grazing, fertilisation and irrigation management practices in an attempt to reduce nutrient loss.

Chris Paul's property

Chris Paul is an active member of the Resource Care Group and has implemented several changes to his property to reduce the impacts of farm management on the stream.

Virtually all of the stream margins through Chris's property have been fenced off using two-wire electric fencing. Along some reaches of the stream the complete exclusion of cattle from the stream margins resulted in uncontrolled aquatic weed growth which threatened to clog the stream channel and encourage surface flooding during heavy rain. To counter the weed growth young cattle are periodically grazed along some riparian strips. The expectation is that they will control some of the instream and riparian margin weeds but cause minimal damage to stream banks because of their lighter body weight.

Aquatic weed growth is a frequently experienced natural response to the exclusion of livestock from stream channels where there are excessive inputs of nutrient to the stream water and minimal shade, as is the case with the Waikakahi. Weed growth will proliferate, and instream fish and invertebrate habitats suffer, as long as the stream is unshaded and nutrient and sediment inputs remain high. The long-term health of the stream (and a corresponding reduction in weed growth) will only occur after the introduction of effective measures to increase shade and reduce nutrient and sediment inputs from surrounding farmland, and even then some studies (see Whangamata Stream in *Case Study 4*) have shown there can be a considerable time-lag before an improvement in instream conditions becomes apparent. Mechanical clearance of stream weed may be the only option on the Waikakahi to prevent flooding, and may be preferable to periodic stream margin grazing because of the effluent and bank damage likely to be contributed by livestock of any age with access to the stream.

Chris has some sections of the stream where belts of trees overhang the northern side of the stream providing considerable shade to the stream channel. Where the shading effect is substantial, aquatic weed growth is likely to be reduced. The planting of shade trees along reaches of the Waikakahi may assist in the control of weed growth (and assist instream life) while steps are taken to deal to the cause of the problem.

Photograph 18:
Blocks of trees on the northern side of a stream can be quite effective at providing shade to the stream.

As a past chairman of the Resource Care Group, Chris is very aware of the need to have all farmers in the catchment actively participating in riparian remedial works, and to encourage those who have been reluctant to alter their water management practices, regular six-monthly workshops and meetings have been scheduled to update progress and set future targets.

Future management options and expectations

Realistic expectations

There is no reason why management improvements along the Waikakahi cannot reduce stream phosphorus and faecal concentrations to relatively low levels but it is doubtful whether nitrate concentrations can be reduced below moderate levels. Wherever irrigation and intensive agriculture coincide, nitrate levels reaching shallow groundwater will always be relatively high. Where a stream occurs in close proximity, stream waters are likely to be the recipients of emerging groundwater, particularly where the substrata is porous and sits on a less permeable layer (ie, it has an elevated water table), as is the case in the Waikakahi.

Noticeable improvements in the quality of stream water will only become apparent after there is a substantial and permanent reduction in the concentrations of nutrients, sediment and bacteria entering the stream from all surrounding farmland. A significant reduction in contaminant inputs is likely to require improved management of surface runoff from irrigation and more efficient utilisation of irrigation water. A reduction in sediment load may require improved land management on the unirrigated hill country to the west of the Waikakahi. Even when inputs are reduced improvement may not occur immediately. A substantial load of sediment has accumulated in the stream channel; the low stream velocity means it will take many years for this to flush out naturally, unless dredging is undertaken.

It is conceivable that if faecal, sediment, and phosphorus concentrations can be reduced to low levels moderate nitrate levels need not interfere with the return of the fishery and the utilisation of the stream for contact recreation. Moderate nitrate concentrations will encourage nuisance aquatic weed growth on exposed streams, but the provision of adequate shade will greatly reduce weed growth even in high nutrient conditions. Increased stream shading will be necessary, even when all other factors have been improved, to enable fish and invertebrates to recolonise the stream. Shading is the only means of reducing summertime water temperatures to tolerable levels.

Farmers along the Waikakahi, under the guidance of the Canterbury Regional Council, have made good progress over a short period, with installing measures to reduce contamination. In three years much of the stream margin has been fenced and several properties have created wide ungrazed or native shrub planted riparian margins. A number of farms have constructed bunding to prevent the flow of excess irrigation water into the stream, and paddock recontouring continues to reduce irrigation water volume. Work is currently underway on transportable bridge designs to replace stock crossings. All work has been done on a voluntary basis.

Despite the measures undertaken stream monitoring results to the first quarter of 1999 show no noticeable improvements in water quality. This exemplifies the time delay that should be expected with stream restoration projects such as these. It also illustrates the complexity of stream andfarming interactions, and particularly how water quality improvements will not generally be achieved by one remedial action alone. In the Waikakahi, the creation and planting of retired riparian margins will not greatly reduce nitrate concentrations in the stream, and may not have much impact on sediment inputs either (especially if sediment is largely originating on the unirrigated hill country).

Setting management priorities

This case study also exemplifies how management for one outcome may not be favourable for another. Tree and shrub plantings along riparian margins will provide important stream shading but could result in less effective filtering of surface runoff than would be expected from a well managed grass margin. Dense, reasonably long grass swards are most effective at intercepting contaminants contained in surface runoff; but grasses do not thrive under shade. Dense grass swards are likely to persevere longer if they are periodically grazed or mowed, so there may be an argument in support of light and occasional grazing by drystock of riparian grass margins in order to maintain grass vigour.

Photograph 19: Fenced off stream margin under grazing by young cattle. Occasional light grazing of riparian margins may serve to maintain a thick grass sward but grazing should be light and at times when the grass is least needed as a filter to surface runoff. In these cases it is recommended that stock be excluded from the stream water itself by temporary electric fencing.

Sensible management should favour a compromise. Where surface runoff is most likely to enter the stream, wide well-managed grass filter strips need to be maintained. Where runoff is less likely to be a problem, trees and shrubs can be planted for shading. There are no generic management rules that will work for all sites; each individual site will require a unique remedial recipe to match the site conditions.

Management priorities (and expectations) need to be clarified before remedial management practices are implemented. In the Waikakahi, it is possible that a reduction in stream sediment loads and the provision of shading is all that is needed to improve the aquatic habitat for recolonisation by fish and invertebrates. However, if improving the water to swimming standards is a priority then faecal contamination will need to be dramatically reduced.

Landowner cooperation

Successful long-term stream management on the Waikakahi requires the full cooperation of landowners and ideally needs to be driven by the local community. The most effective management prescriptions will be those that match the predominant threats and the management priorities to local conditions on each specific site. This is especially so when considering nitrate management. Riparian retirement will be of little or no value in reducing nitrate contamination; instead, new and innovative improvements to irrigation, pasture and fertiliser management are needed to reduce what leaches through the soil.

Management suggestions

The following are some management practices that may lead to the improvement in Waikakahi water quality. Many of these are currently being implemented by local farmers. Some of the practices listed require a commitment of capital, but many require only more careful and commonsense management planning. Most are likely to benefit farm profitability to some extent.

- Accurate recontouring of all irrigated pasture using laser technology will reduce watering times and the amount of water required to cover the entire pasture. This will reduce nitrate leaching and reduce the likelihood of surplus water accumulating at the end of paddocks and flowing to the stream.
- Structures, such as bunding, placed between border-dyked paddocks and stream banks will further reduce the likelihood of excess irrigation water reaching the stream channel.

Photograph 20: Recently cultivated margins of Waikakahi Stream. Note small earth mound (bunding) along the left of the stream (also on the right), created to reduce direct runoff from paddocks to the stream.

- All farmers should be encouraged to fence stock permanently from the stream channel. Currently, the stream water is periodically unsuitable for stock to drink. Stock health problems will be avoided if stock are excluded from the stream.
- Densely grassed riparian margins will serve to intercept overland flow (from irrigation and rain) and trap the contaminants contained in it. The wider the grass margin, the more efficient the removal of contaminants.
- Where grassed riparian margins are to be maintained by periodic grazing, grazing should be light so as to maintain a long sward and should be at a time (eg, autumn) when the filtering effect of the grasses is less important. If stock are inclined to occupy the stream itself temporary electric fencing to prevent this would be advisable.
- Fertiliser and effluent (if applied by spray boom) should not be applied to pasture immediately prior to irrigation.
- Irrigation should not follow immediately after a pasture has been grazed. Careful management and planning of grazing rotations, fertiliser and effluent application, and irrigation timing will reduce unnecessary (and costly) fertility loss and reduce stream and ground water contamination. Retained soil fertility will result in improved pasture productivity.
- Where practical (and where flooding will not ensue), fill in drainage channels where they flow through retired grass filter strips and allow the water to spread out over the grassed area to maximise the filter effect.
- Install bridges to reduce the need for stock or vehicles to ford the stream.
- Plant trees and shrubs along portions of the stream where surface runoff is less likely to occur. The plants will provide important stream shade and, once established, will require minimal maintenance. Tree plantings in riparian areas can serve as useful stock shelter if positioned in the path of prevailing winds, and can improve the appearance and natural values of a property.
- The provision of stream shade is the most effective and long-term method for controlling aquatic weed growth. However, in stream sections where trees and shrubs are not appropriate, periodic mechanical dredging of instream weed may be the only practical means of controlling this problem. Dredging may also enable some of the accumulated streambed sediment to be removed.

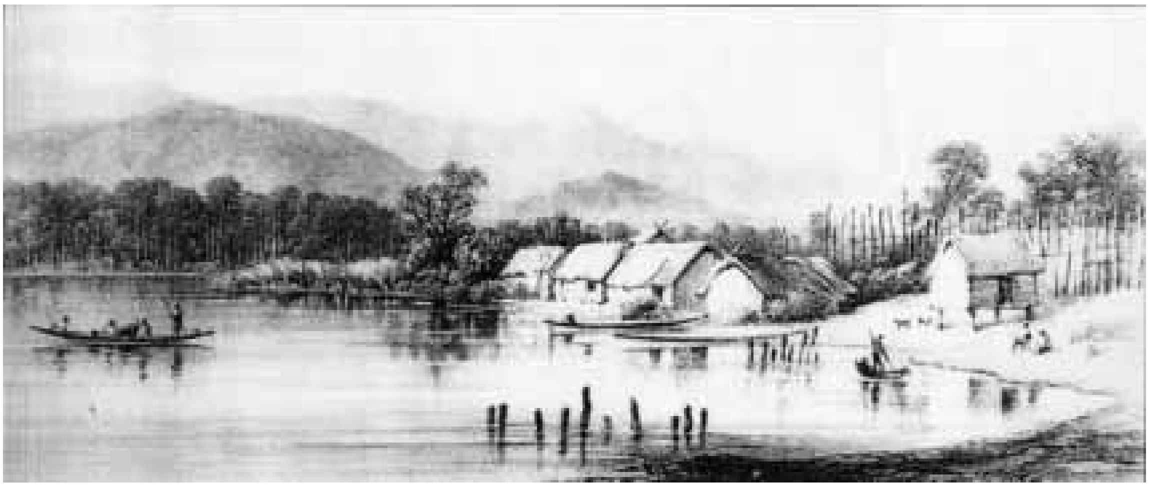
More source-focused water monitoring is necessary to determine where and when the greatest contaminant concentrations are originating so that management can target the worst areas.

Case Study 3: Waipunahau (Lake Horowhenua): restoring the mauri

Waipunahau, known to many as Lake Horowhenua, is the heart of the ancient iwi, Muaupoko. For centuries it has been their vital treasure (taonga) and food bowl (kumete), providing tuna (eel), inanga (whitebait), freshwater koura (crayfish), patiki (flounder), kaakahi (freshwater mussels), waterbirds, and kereru. Dense, diverse forests of kahikatea, pukatea, and rata on the lake margins and wet areas, and nikau, totara, karaka, matai and rimu once extended from the lake to the inland Tararua Range and provided food, shelter and a place to live, and with the lake, cultural and spiritual sustenance for Muaupoko. As lake trustee Jim Broughton states, "Our people did not need to garden any kai".

Today, no forest remains and there are no kereru. The quality of the lake water and its riparian margins have deteriorated to such an extent that the lake's mauri, its lifeforce or capacity to sustain life, has been seriously compromised. Locals continue to collect eels and kaakahi, and the introduced trout and carp, but the fisheries are depleted when compared to their abundant past. The water is no longer drinkable and algal blooms and weed growths, and the subsequent offensive odours as the blooms die and rot, make the lake less than attractive for recreational and cultural pursuits. Transcripts from the late 1800s highlight the changes:

> *The lake lay clasped in the emerald arms of bush which surrounded it on every side save immediately about where we stood… Straight and tall timber grew to the water's edge, fringed with flax and nodding manuka, and over the bush... pigeons flew literally in their thousands.* (Hector McDonald, in Forbes S, 1996)



Photograph 21: This lithograph of Waipunahau (Lake Horowhenua) in the 1860s shows the idyllic setting which its owners are aiming to restore. The pa is probably Te Rae-o-te Karaka. From CD Barraud, New Zealand Graphic and Descriptive. (Otaki Historical Society Journal*, Vol 21, 1998, p 66.)*

Muaupoko, through their Lake Horowhenua Trust, own the lake bed, a riparian margin around the lake edge and the outlet stream, Hokio, which runs to the sea. They have embarked on a massive restoration campaign to clean up the lake: improve the water quality and revegetate the lake margins – restore its mauri and its mana. The aim is to see the birds and the fish return and for the water to be drinkable. This is their story.

Physical details

Lake Horowhenua is a freshwater coastal dune lake located just west of Levin township. It has a surface area of 2.9 km^2 and an average depth of less than 2 metres.

The lake is drained by a single outlet, Hokio Stream, which runs 5 km to the sea. A weir at the outlet controls the lake at a constant level.

Surface flows account for only about half of the water inputs to Waipunahau; groundwater inputs account for the other half. The groundwater enters the lake mainly via a number of submerged springs along the lake's eastern shore, and is also a significant source of the lake's largest surface water supply, Arawhata Stream, and several other small streams.

The surface catchment area feeding the lake is 43.6 km^2, and nearly 20 percent of that is occupied by Levin township. Land use in the remainder of the catchment is rural, and includes pastoral, dairying, piggery, poultry and horticultural activities. Arawhata Stream supplies 70 percent of the surface inflow and Queen Street Drain, the main urban drainage channel, supplies 15 percent of the surface water to the lake.

The groundwater catchment is suspected to be considerably larger than that supplying surface flow. Aquifers inland from the lake are fed from the Tararua Ranges.

The average annual rainfall is 1095 mm. Half of the runoff that arises from the rainfall occurs in the winter months of June to August.

The topography of the surface catchment is generally flat, and includes a mix of very flat, low-lying areas of peaty soils (formerly swamps), higher "sandstone uplands" and gravel plains.

Understanding the problem

Water quality

Waipunahau is in an advanced state of eutrophication (hypertrophic). Eutrophication is a state of enrichment characterised by high levels of plant growth, promoted by increased nutrient inputs. Although lakes such as Waipunahau are predisposed to eutrophication, the process has been accelerated over the last century by the clearance of the riparian and wetland vegetation around the lake and tributary stream margins, by the clearance of forest cover over the catchment, and by the development of intensive agriculture and horticulture. The resulting increased intensity of surface runoff and the lack of vegetation will have increased the volume of sediment entering the lake and inflated the volumes of nitrogen, phosphorus and faecal material containing bacteria. It is likely that the groundwater, which supplies the lake with much of its water, will also have increased nitrate levels due to leaching through the plains gravels.

For many years cattle grazed to the water's edge and browsed on the remaining riparian vegetation, contributing dung and urine directly to the lake.

Most of the swamp and wetland areas that existed around the lake margin and at the seepage zones where groundwater emerges have been drained. The drainage has removed the important sponge and filter function of these wet areas and accelerated the rate of water flow and increased the capacity for contaminants to be carried with it.

The discharge of treated sewage directly into the lake from 1952 to 1987 has contributed significantly to the lake's elevated eutrophic state. And while Levin's sewage is now discharged to land, some seepage appears to be reaching the groundwater and entering the lake. Evidence suggests that the sewage discharge has been responsible for increased sediment and nutrient levels on the lake bottom, with much of the sediment probably occurring as a result of the decaying remains of algal and plant growth. Abnormally large growths of algae and weed occur periodically in the lake. In the summer of 1995/96 the whole northern half of the lake had extensive weed growth extending right to the lake surface.

Bacterial levels in the lake are generally within safe limits for contact recreational use, although not for drinking.[4] Occasionally, bacterial contamination has well exceeded contact recreation levels. This usually coincides with recent rainfall and is probably the result of faecal contamination from farmland runoff.

Waipunahau's natural shallowness contributes to the problem. It means the water body becomes warmer and the lake bottom receives more light in summer than would deeper lakes. This, in conjunction with elevated nutrient levels, promotes more rapid algae and aquatic plant growth. On the positive side, this shallowness also provides feeding opportunities for wading birds.

Aquatic habitat

There is no doubt that the fish life in the lake have diminished considerably since pre-Pakeha times but little quantitative information exists on the magnitude of this decline and on the precise causes. More detailed information is probably necessary before an effective programme to restore the lake's life-supporting capacity can be determined.

Little appears to be known about the diversity and abundance of other native fish and invertebrate species in the lake, although kokopu can still be seen in some of the small streams that feed the lake.

Riparian habitat

Only small pockets of naturally occurring remnant indigenous vegetation remain around the lake edge. The forest that once grew to the lake edge is gone and the large stands of flax and raupo that once characterised the margin no longer exist (pre-restoration). The lake margin vegetation would have supplied food and habitat to many animals living in and alongside the lake; its clearance has probably contributed to the reduced lake fishery.

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4 Mahinga kai includes the activities of accessing, harvesting and using resources. Any resources that are taken must be fit for cultural use. This means that food must be able to be consumed and water must be suitable for drinking.

Photograph 22: View across Waipunuhau to the west. Now largely a tree-less landscape; much of the lake once consisted of forest to the water's edge.

Waipunahau Condition Score: Contaminant Loading and Habitat Condition

Bacteria: MODERATE
periodically high levels from farmland

Nutrients: HIGH
continuing high inputs from surrounding rural and urban land

Sediment: HIGH
because of advanced eutrophication and input from farmland

Aquatic habitat: POOR
because of poor water quality, loss of riparian vegetation and perhaps, over-fishing

Riparian habitat: POOR
little remains of the original riparian vegetation.

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

Managing the problem

Land use and management issues and constraints

Restoration expectations

Unlike streams and rivers, which can flush themselves of periodic contaminant inputs, lakes tend to accumulate and store sediment and nutrients. Their physical and biological state can reflect the cumulative history of land and water management in the catchment; even with a reduction in catchment inputs restoration of lake health will be a very slow process and it will not be possible to restore some aspects to a pre-agricultural state. For example, increased sediment deposits on the lake bottom contain a nutrient store so large that it may take 30 years for lake nutrient concentrations to reduce to acceptable levels. The sediment that has accumulated on the lake bottom will probably never be removed.

Managing the catchment

Muaupoko own the lake, the Hokio Stream and a margin one chain wide (20 m) around the lake edge. Their own restoration efforts must therefore be confined to this margin and as a consequence, their efforts will be very much a last line of defence against the negative influences on the lake and its waters.

The causes and sources of water quality contamination lie on the surrounding farmland and from the township of Levin. By the time the contaminants enter the lake margin they are almost unmanageable, occurring either in the groundwater which emerges beneath the lake surface or being carried in streams and drains which flow unimpeded directly into the lake. The only way some of the contaminants could be removed once they enter the surface waterways would be to fill in the stream and drain channels where they enter the lake riparian zone and encourage the water to disperse over and be retained within a large area of lake margin vegetation (flax, raupo, reeds and sedges) before it flows to the main body of lake water.

The longer the water could be held in this zone the greater the volume of nitrogen likely to be removed from the system by denitrification and, perhaps, sediment and faecal material would be more likely to settle out and not enter the lake itself. The Queens Drain which carries stormwater from Levin could be quite effectively filtered if allowed to fan out through a flat area of riparian vegetation before entering the lake.

Research findings (see Whangamata Stream, *Case Study 4*) also suggest that the weed growth that occurs in high nutrient streams has considerable capacity to strip stream water of its nutrients. For the nutrient stripping effect to occur the streams must be fenced off from stock so that the weed can grow, and the channel should remain undredged so that the weed can occupy the stream channel. The more weed the better the stripping. The weed will tend to clog the stream and may cause some local water back-up and flooding, so this approach should only be used where flooding is unlikely or tolerable.

Sources of the contaminants need also to be managed on the farmland before they leach to groundwater and before they get carried by surface runoff to streams and drains. The support of the local community and landowners throughout the catchment is essential if significant improvements in Waipunahau water quality are to occur and Muaupoko are to achieve their objectives of replenishing the lake fishery and enhancing water quality to a drinkable standard.

The restoration of the lake margin will, however, contribute substantially to restoring other aspects of the mauri of the lake and will do much to kick-start many of the ecological processes that are vital to the functioning of an indigenous ecosystem and which have been absent from Waipunahau for so long.

Amenity values

The lake is used by the general public for windsurfing, sailing and rowing; however, the value of the lake for these activities and swimming has been reduced by the excessive aquatic plant growth and poor water clarity. While the aesthetic appeal of the lake and its surrounds will improve considerably with margin plantings, improvements to water quality and appearance will require land and water management improvements elsewhere in the catchment.

Summary of water-related issues affecting management/restoration decisions

- Waipunahau requires a substantial reduction in nutrient and sediment inputs throughout the catchment before water quality will improve.
- Improvement in the diversity and abundance of the fishery is likely to require a significant improvement in water quality.
- Lake margin revegetation will provide food and habitat for indigenous terrestrial and aquatic animals, assist in restarting ecological processes and improve the aesthetic appeal of the lake.
- Restoration of the lake water quality will be a long and slow process.

The Waipunahau restoration plan

In late 1996, Lucas Associates were commissioned by the Lake Trustees to prepare the lakeshore replanting plan, which they did in consultation with Muaupoko, ecologist Geoff Park and archaeologist Susan Forbes. The plan is a long-term one (perhaps 20 years or more) and maps out revegetation strategies for the entire 13-km perimeter of the lake. The lakeshore has been divided into nine stretches, and each stretch further subdivided, producing 75 segments each about a hectare in size. Criteria were developed to prioritise their planting order, and provision made for recognising known special sites such as pa, tauranga waka, midden and clearings, as well as special sites yet to be discovered. The full length of the shore was mapped as seven ecosystems, based on drainage, soil, elevation and shelter, and making allowances for sites and traditional clearings special to Muaupoko. For each ecosystem, two alternative planting options have been offered. For each lakeshore segment, and responding to archaeological, historic or visual landscape considerations, the owners can choose either a shrub option or a forest option.

Because of the exposure of the site to prevailing wind (a product of forest clearance), a three-stage planting regime has been recommended. Stage 1, which has virtually been completed, involves the planting of hardy, colonising species as a nurse crop for the later planting of shrub and tree species. More tender species such as rimu, matai and ferns will be planted when a canopy has established. Harakeke (flax) has been used as the main species for Stage 1. To date, some 100,000 flax fans, sourced and split from remnant flax stands in the adjacent area, have been planted.

Photograph 22: Planted flax, some of the 100,000 planted in recent years, beginning to emerge above the lake margin grasses.

The primary aim is not to recreate the vegetation of the past, but to maximise ecological opportunity – to kick-start nature. All parties involved realise that Waipunahau is a man-modified lake surrounded by altered land and water influences. The aim of Muaupoko is to replant and repair the ecological health of the lake and its surrounds sufficient for it to be self-sustaining, to regain its mauri.

In 1998 the Manawatu-Wanganui Regional Council, in conjunction with the Lake Horowhenua Trustees, the Department of Conservation, and the Horowhenua District Council, produced a Lake Horowhenua and Hokio Catchment Management Strategy. The goal of the strategy is:

> *To restore the water quality of Lake Horowhenua and the Hokio Stream to a level that enables a satisfactory improvement in both cultural and amenity values and the life-supporting capacity of the lake and the stream by 2018.*

Much of the focus of the strategy is on improving water management on land throughout the whole catchment.

Weeds

The planted riparian margin has 13 km of edge facing out onto pasture land, and because of this is particularly exposed to weed invasion. Trustees, elders and trainees have undertaken a weed identification programme amongst themselves, and the iwi have initiated a community awareness programme to encourage Levin householders to eliminate exotic plant species that pose a threat to the lake margin. Many, such as euonymus, privet and ivy, have been grown as common garden plants.

Funding and implementation

The planning and work undertaken to date has been supported, by way of funding or the provision of voluntary labour, by many agencies including the Lottery Grants Board, Labour Department, Employment Service (as it was once known), Horowhenua District Council, Department of Conservation, the Horowhenua Branch of Forest and Bird, the local polytechnic and local schools.

Having completed Stage 1 of the planting, the Lake Trustees are now embarking on the construction of a native plant nursery facility adjacent to the lake. The aim is to grow the native tree and shrub seedlings for the Stage 2 plantings with the assistance of trainees, mostly

Muaupoko rangitahi (youth), attending 42-week horticulture training courses in Levin. The nursery facility, complete with shadehouse, propagation sheds, lecture room and stand-out area should be producing the first crop of native seedlings by 2001.

Managing the inputs: management suggestions for Patiki Stream

Patiki Stream is one of several small streams flowing into Lake Horowhenua. It enters the lake on its western side and is fed from a spring and supplemented with farm runoff during the winter.

The stream is unfenced for much of its length and livestock, particularly cattle, have free access. It is a typical agricultural stream: it has little or no natural riparian vegetation; it is grazed to the water's edge; and has considerable aquatic weed growth (which is less noticeable in unfenced sections due to grazing by stock). The lower section of the stream flows through what was once a riparian wetland but which has been drained and converted to pasture. Despite the modifications of agriculture the stream still sustains native fish populations including kokopu and eel.

Better management of streams such as Patiki and better management of the contaminants that threaten stream water quality in the lake catchment is essential if marked improvements in the quality of the lake water are to be achieved. These streams and drains are significant sources of nutrients, sediment and faecal bacteria which invariably accumulate in the lake.

Stream management recommendations

The following actions will reduce the contaminants entering the stream and eventually the lake:

- Fence off both sides of the stream to exclude stock permanently.
- Allow sufficient room (5–10 metres) on the stream side of the fence for a grass filter to grow, or better still, plant the stream sides with sedges and flax. This will protect the banks against erosion, filter any surface runoff from adjacent paddocks, and provide some essential shade to the stream and its invertebrate life.
- Apply sensible stock, fertiliser and cultivation practices so that the volume of surface runoff, and the concentration of contaminants it carries, are minimised.

Contaminants will still inevitably enter the stream water, and there are some options available that may serve to intercept some of the stream water contaminants before they enter the lake. The last few hundred metres of the Patiki Stream flow through a flat, previously drained wetland area. The remnant of a stand of cabbage trees, with stems and roots damaged by cattle, still occupy some of this flat.

Photograph 24: Lake outlet of Patiki Stream. Only the last few metres are currently fenced from stock.

If the Patiki channel could be filled in for some of the last portion of its journey to the lake and the water encouraged to fan out over a wider area the grasses, sedges and flax growing over the lake margin would further slow the speed of water and filter and trap the sediment, nutrient and faecal particles before they reached the lake (as has been described above). This would require the retirement of some of the privately owned pastureland through which the stream flows, but would have the added benefit of protecting the cabbage tree stand from further physical damage.

Case Study 4: Whangamata Stream: riparian, stream and water quality changes over 24 years of retirement

Although riparian management and restoration works have occurred in one form or another for several decades, very little information exists as to the changes that have occurred over more than just a few years. Even today, few riparian projects are being monitored regularly and repeatedly with a focus on the changes that occur as a result of management practices. The consequence of this is that although we have reasonable confidence that the riparian practices advocated will improve water quality, instream habitat and riparian habitat, we have very little quantifiable evidence to substantiate this. The Whangamata Stream on the northern edge of Lake Taupo is an exception, providing a unique, documented 24-year history of rehabilitation (Howard-Williams and Pickmere, 1999) and a clear insight as to what we can expect from riparian management and how quickly we can expect it.

Photograph 25: 1974 (pre retirement)

Photograph 26: 1981

Photograph 27: 1985

Photograph 28: 1990

Photograph 29: 1998

Photographs 25–29: Changes in the Whangamata Stream 1974–98. The photographs were taken standing on the Whangamata Road Bridge looking downstream over Section B (the 1974 photograph was taken from just to the left of the road bridge).

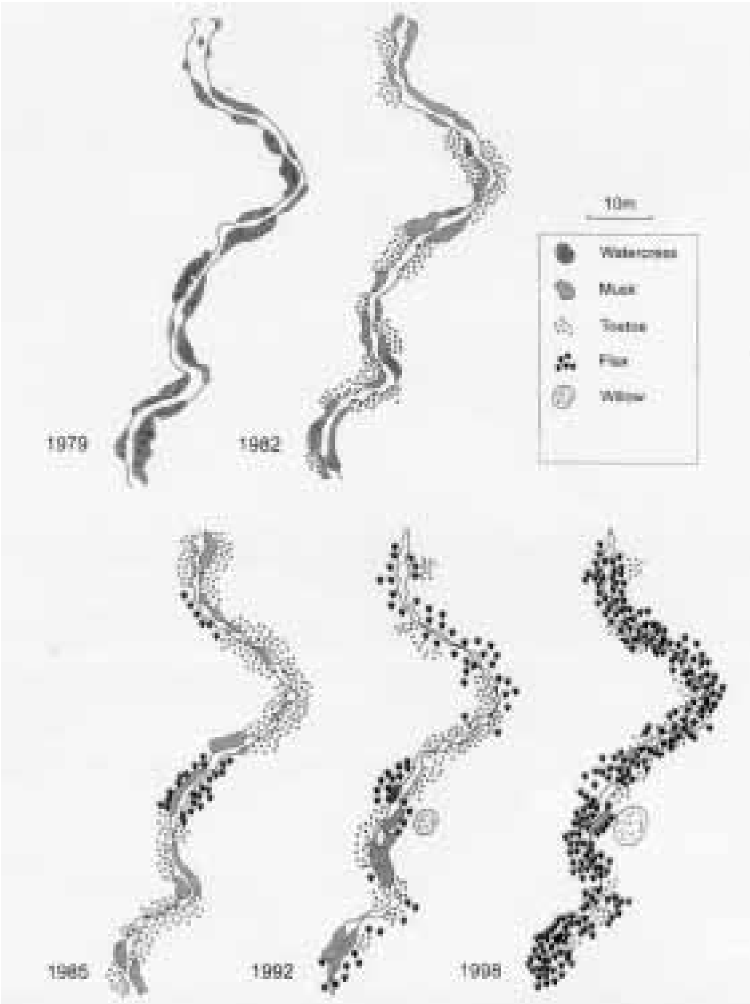


Figure 10: Schematic maps of the upper 250 metres of stream in Section B over time. *(Howard-Williams C and Pickmere S, 1999,* Science for Conservation *114)*

Understanding the problem

In 1975 the Whangamata Stream was typical of streams in the vicinity of Lake Taupo. It was wide and shallow, had eroding banks, and was heavily grazed right to the stream edge. In 1976 the margins of the stream were fenced off and retired from grazing as part of the Lake Taupo Catchment Control Scheme for the principal purpose of reducing erosion and sediment input to Lake Taupo. Mitigation of the effects of nutrient runoff from farmland was also seen as an important objective. Water quality, wildlife and vegetation changes have been monitored for much of the period from 1974 until now.

The Whangamata Stream is a small (second-order) spring-fed stream, 2 km long, flowing into the northern edge of Lake Taupo near the township of Kinloch. It has long been a significant trout spawning stream. Its condition in 1974, prior to any rehabilitation, was not dissimilar to many existing streams flowing through pastoral farmland today, and so the sequence of changes over the 24 years following retirement are likely to give a relevant pointer to what can be expected from current riparian initiatives.

Managing the problem

Initial rehabilitation

In 1976 the entire length of the stream was permanently fenced to exclude farm livestock. Some plantings of flax and toetoe occurred in the late 1970s, and the Department of Conservation has carried out extensive native plantings since 1990 along the lower reaches of the stream; a significant cover of flax and toetoe has developed in some areas as a result. Small stands of Tasmanian blackwood, eucalypts, Douglas fir and assorted ornamental deciduous trees have also been planted in pockets during this period. All other changes in vegetation have occurred naturally.

Inputs from surrounding farmland

Throughout the duration of this study the land surrounding the stream margins has remained predominantly as drystock farmland. No tributaries feed into the Whangamata so inputs from agriculture arrive laterally as surface runoff and groundwater seepage, or at the head of the stream from the groundwater that rises at the two springheads that feed the stream. The residence time of the groundwater reservoir feeding the stream is not known but can be expected to reflect inputs from surrounding farmland.

Monitoring the changes

Vegetation changes

Prior to the installation of retirement fencing in 1976 the stream was wide, shallow, and carried a high load of shifting pumice from an unstable bed. The banks were heavily grazed and trampled.

By 1979 the banks had stabilised and had become colonised by watercress and floating sweetgrass which grew over the water surface each summer. By the early 1980s aquatic and semi-aquatic vegetation such as watercress and monkey musk choked the channel in summer and autumn, impeding the migrations of spawning trout.

Natural growth of toetoe and flax, supplemented by plantings of these species, began to appear along the stream banks by 1979, and between 1981 and 1984 the channel edges became significantly shaded, so that the low growing streambank plants began to disappear in patches. However, the vegetation remained sufficiently dense in some reaches of the stream to impede the migration of trout so that manual clearing of the channel was necessary each autumn. This continued on a reduced scale until 1993.

By 1985 the riparian vegetation had developed to the extent that the first fernbird was recorded, and by 1986 the stream channel was hidden beneath overhanging flax and toetoe. By this stage the areas of stream surface occupied by watercress and monkey musk had reduced although the areas that remained continued to be an obstacle to fish passage.

Over the first six years following riparian protection (1976–1982) the total number of plant species growing in the riparian zone increased from 24 to 40. This was followed by a rapid rise in diversity between 1982 and 1986 to just over 100 species, of which native species comprised almost 50 percent. A further 17 species arrived between 1986 and 1992. By 1998, 148 species were present of which 60 (41 percent) were natives.

The increase in diversity was accompanied by a decrease in aquatic species with 12 disappearing between 1982 and 1993 and several decreasing noticeably in abundance. By 1998 musk, watercress and floating sweetgrass, which had dominated the stream banks along the entire length of the stream in the late 1970s and 1980s, had become only occasional plants never exceeding more than 5 percent cover in any reach.

Between 1990 and 1998 there was a significant increase in the number of woody tree and shrub species, with natives such as cabbage tree, karamu, tutu, tree ferns, manuka and mahoe becoming more apparent. The invasive grey and crack willows also arrived naturally between 1986 and 1993.

The Whangamata Stream is now effectively a continuous native riparian wetland corridor along its full length from the springs to the lake, 24 years after it was first fenced.

The presence of fernbird in the riparian zone of the Whangamata Stream is a good indicator of the degree of rehabilitation achieved. Fernbird are a secretive species with a restricted habitat range and they require a sizeable area of suitable wetland habitat before they will establish.

Fish passage

During the first five years after riparian retirement, the semi-aquatic plant community which grew along the banks was dominated by watercress, which died back each autumn to allow a clear channel for fish passage. Spawning increased dramatically over this period as a result of bank protection, vegetation cover along the banks and an open central channel. Between 1983 and 1989 the watercress was replaced by musk which did not die in winter. This plant caused blockages over long stretches of the stream, preventing spawning migrations. The Department of Conservation undertook manual weed clearance at first, which was later replaced by the use of selective herbicides. By 1994 weed clearance was only required on the lower reaches of the stream to allow fish to make their spawning runs, and by 1998 no clearance was required.

It took 18 years of mostly natural plant succession before the stream and its margins had recovered sufficiently to allow the natural unhindered passage of fish life.

Water quality

Nutrient concentrations and flows were measured at two points in the stream; one at the head of the stream just below the junction of the two spring outflows, the second 250 metres from Lake Taupo, and at the spring itself.

Nitrate nitrogen

The variations in nitrate nitrogen concentrations over the 24-year recorded history of the stream are quite surprising. The monitoring between 1996 to 1998 has recorded the highest nitrate readings for the entire period of nitrate measurement dating back to 1979, both at the top and bottom monitoring sites. Both readings are now virtually the same as those recorded at the spring. The spring nitrate concentrations have not changed over 20 years of monitoring so the conclusion must be that there has been a significant reduction in the nitrate removal capacity of the stream channel itself.

At the time of riparian retirement, the Whangamata Stream showed water quality trends typical of most pasture streams in New Zealand. Firstly, there was a marked seasonal pattern in nutrient concentrations with nutrient levels in the stream water falling through the summer. This is due to the seasonal growth of aquatic and streambank vegetation which absorbs nutrients rapidly from the water through the growing season reducing the concentrations remaining in the water. Nutrient concentrations increase again in winter when plant growth rates reduce. Secondly, there is a decline in nutrient concentrations with distance downstream, especially in mid to late summer. This occurs because of the collective nutrient stripping capacity of instream vegetation.

Consequently, the greater the aquatic and semi-aquatic weed growth the greater the reduction in nutrient concentrations with distance downstream and the lower the absolute concentrations of nutrient by late summer, especially at downstream sites. The Whangamata increasingly showed these tendencies between 1976 and 1989 as the level of streambank and channel vegetation increased. By 1989, mid summer downstream nitrate measurements were almost zero.

Maximum nutrient removal was recorded in 1987/88 when 787 kg of nitrogen and 71.7 kg of phosphorus were removed from the stream waters by biological activity. By 1992/93 these amounts had fallen by 85 percent, and by 1996/97 the removal rate was negligible. This occurred as a consequence of the natural disappearance of most of the aquatic and semi-aquatic streambank vegetation caused by the increased shading from other riparian plant species. This explains why nitrate levels at upstream and downstream sites are now much the same and why nitrate concentrations in the stream are now as high as they have ever been over the period of recording.

Dissolved reactive phosphorus (DRP)

Phosphorus concentrations and instream uptake has followed very similar patterns to that of nitrate nitrogen. The greatest phosphorus removal occurred in the same year as for nitrates, and the variations between upstream and downstream stations and the greatest lowering of downstream phosphorus concentrations occurred when instream weed growth was at its greatest. By 1998, DRP concentrations were similar at both monitoring stations and much the same as DRP levels at the spring.

Implications for riparian management

The findings of this study provide useful pointers to guide the development of future riparian management strategies and a more realistic picture of what our expectations for the speed of recovery should be. It is, however, important to realise that the Whangamata Stream is not typical of most agricultural streams in that it is not fed to any extent by surface runoff; it flows through highly erosion-prone pumice, and the feeding springs are high in nutrient.

Summary and extrapolation of Whangamata findings

- The retirement of pasture streams from livestock and grazing may lead to a prolonged period (18 years in the Whangamata) of excessive aquatic and semi-aquatic plant growth which may clog the stream channel and impede the passage of fish in systems prone to macrophyte growth.
- The period of greatest instream nutrient removing capacity is when aquatic plant growth is at its maximum. The removal of aquatic vegetation by natural or manual means will reduce the stream's nutrient stripping capacity; the complete removal of aquatic vegetation may eliminate the stream's capacity to remove nutrients.
- Instream fish and invertebrate habitat may improve briefly upon the exclusion of stock, but will require the elimination of extensive growths of aquatic vegetation (by shading) before habitat conditions improve significantly.
- The natural arrival of successional plants to riparian margins is dependent upon the proximity of species suitable for occupation, but the recovery of riparian vegetation from grazed pasture to predominantly natives may take several decades.
- The planting of appropriate riparian vegetation, especially natives, will hasten the process of plant succession and habitat recovery.
- Riparian zones with a significant proportion of shading trees and shrubs may reduce the capacity of the stream to remove nutrients from the water by biological means, and may also reduce its effectiveness as a nutrient and sediment filter to surface runoff and overland flow.
- Improvements in water quality may take a considerable period of time and may not occur at all where riparian margin retirement alone is undertaken, ie, the causes of deteriorating water quality may have to be dealt with at the source. The expectations of landowners, government officials and the public need to be set at realistic levels in terms of the time required to achieve improvements and the methods by which those improvements will occur.
- The rehabilitation of riparian margins to relatively natural assemblages of plants is likely to benefit instream life, control streambank erosion and improve wildlife and biodiversity values, but may be of little or no value where nutrient stripping by instream uptake is a primary management objective.
- Consequently, efforts that manage and restrict the concentrations of agricultural contaminants produced, reduce the likelihood of their transport to riparian areas, and/or intercept their passage before they reach the riparian zone or stream are likely to reap the greatest improvements in water quality.

Case Study 5: Peat farming in the Waikato: striking a balance between production and the environment

Half of New Zealand's peat occurs in the Waikato region. Waikato peat soils cover about 94,000 ha and contain an estimated 2,700,000 m^3 of peat. About 80 percent of our peat soils have been developed, mostly for farming. The remainder is managed as conservation areas for wildlife and flood protection. (See Environment Waikato's 1997 publication, *For Peat's Sake,* for a wide-ranging view of peat in the Waikato.)

Peat wetlands are home to a unique diversity of indigenous plants and animals, and they often serve as important storage areas for floodwaters. Only 30,000 ha (25 percent) of the estimated original 110,000 ha of Waikato wetlands remain, and their continued healthy existence is dependent upon how carefully the land around them is managed.

Managed correctly, peat can be a highly productive medium for agriculture, but drainage and cultivation can lead to irreversible peat shrinkage. This can reduce the life of the peat soil – shrinkage can continue until there is no peat left – and compromise the status of adjacent peat lakes and wetlands. For peat farming to be successful and profitable in the long term, farmers must find a balance between maintaining the water table at levels low enough to optimise production, yet high enough to minimise shrinkage and the impact on adjacent wetlands and peat lakes.

Understanding the problem

Peat formation

Peat is formed when wetland plant material dies but is prevented from decaying in a normal way by the presence of a high water table. There are two broad categories of peat:

- Eutrophic peats (sometimes referred to as "low mor" or "fen" peats) form where organic matter from dead vegetation builds up in wet hollows or small lakes until the lake is filled or the upper limit of the groundwater is reached. Because they are fed by groundwater eutrophic peats can be relatively fertile and sustain a diversity of woody wetland shrubs (such as manuka) and sedges. The Whangamarino wetland adjacent to the Waikato River north of Huntly is an example of a large eutrophic peat.
- Oligotrophic ("high mor") peats form where rainfall is the source of water. They are often elevated above surrounding land and so are sometimes referred to as peat domes. Because rainfall contains few nutrients oligotrophic peats have a low fertility and are quite acidic. They generally support only low growing plants tolerant of low fertility, such as sphagnum moss and *Sporodanthus.*

Peat soil properties

Undeveloped peat is mostly made up of organic matter and a small amount of mineral matter. As peat is developed, by cultivation and drainage, the top layer becomes aerated and the organic material begins to decompose and mineralise (oxidise). As a result it shrinks, becomes denser and contains less organic matter and more mineral material.

Undeveloped peat typically has a low pH of about 4.2, low fertility (very low nitrogen levels) and a high carbon content. The high carbon content gives peat a good physical structure for growing but it requires the addition of considerable applications of lime and nitrogen on an on-going basis to produce good pasture.

Cultivation

Cultivation causes peat to shrink twice as fast as it does under pasture. However, cultivation is necessary to establish and replace pasture. The top 200–250 mm of peat, the maximum rooting depth of pasture and crops, needs to be aerated and have lime and fertiliser incorporated before pasture grasses and rotational crops such as maize can thrive. Deep initial cultivation is necessary because as the peat shrinks over time pasture roots get closer to the underlying low pH and low fertility soil.

Peat shrinkage will be reduced if the intervals between cultivation can be extended as far as possible. This can be achieved by good deep initial cultivation, and good pasture management practices to prolong the life of the pasture.

Water quality and drainage

Surface water and groundwater draining peat areas is generally of poor quality for drinking and stock watering. It has a naturally low pH and is high in tannins, which is the reason why the water in drains looks tea-coloured. It also tends to be high in iron, which taints the water and clogs pipes when it precipitates out (Environment Waikato, 1997).

The optimum regime for water table management on peat is to lower the water table in winter, and so lessen the risk of soil saturation and consequent stock induced pugging and pasture damage, and raise the water table in summer (up to within half a metre of the surface), so as to reduce peat shrinkage and lessen peat drying (which retards pasture and crop growth). In most situations this level of water table control is not physically possible although reasonable water table control can be achieved by appropriate positioning and depth of drains and good drain maintenance (including fencing and weed control).

There are two principal methods of peat drainage within paddocks:

- conventional open ditch or box drains
- “hump” and “hollow” formations.

Conventional ditch drains often form the boundaries between paddocks and feed into secondary drains. They act by drawing water from the water table and maintaining it below the pasture root zone. Surface runoff is improved with this system if the paddocks are domed or humped towards the centre.

Hump and hollow contouring of paddocks encourages surface water and groundwater to move to the hollowed portions of the paddocks from where shallow spinner drains carry water to the larger secondary and main drainage systems. The hollows do not need to be fenced from stock but to prevent pasture damage from pugging it is important that the spinner drains are well maintained.

Photograph 30: Freshly cleared "spinner ditch" on the property of JD and RD Wallace. The spinner ditch sits at the lowest point of the 30 metre wide hump and hollow contours, and functions most effectively when it is kept shallow.

Because peat soils have naturally high water tables and farmed peat is characterised by considerable surface and channelised drainage, waterways on peat farmland are vulnerable to contamination from sediment, faecal bacteria and nutrients derived from stock effluent and fertiliser. Most developed peat is now occupied by intensive dairy farms which further intensifies the risk of water contamination. Poorly managed drains, stock, pastures and crops can lead to extreme levels of water contamination.

Managing the problem: JD and RD Wallace Ltd dairy farms, Cambridge

David Wallace and his father, JD Wallace, developed much of the peat land that lies between Cambridge and Te Awamutu. JD purchased 640 acres (about 260 ha) of undeveloped peat in 1949, on what is now referred to as the Moanatuatua Peat Dome (an oligotrophic peat), and set about draining and converting it to farmland. Fifty years later JD and RD Wallace Ltd now operate productive dairy farms on 1400 ha of peat land in this area.

In many respects the Wallaces pioneered the techniques for the development and management of peat soils for farming. They introduced the concept of humping and hollowing and continue to practice this method of drainage on all of their peat dairy farms. All of the land developed was recontoured into gentle 30 metre wide mounds ("humps"); the wetter the peat the higher the humps. There was not the technology nor machinery available in the 1950s that there is today and conversion of such difficult land required considerable innovation. The greatest challenge was to clear, contour and cultivate the land without constantly having the crawler tractors stuck to their axles in saturated peat. Hand-made wooden extensions to the dozer tracks greatly improved the ability of machinery to stay afloat. The arrival of hydraulic technology in the 1950s (in the form of tilt controls on bulldozer blades and drain cleaning devices) revolutionised the precision and speed of earth moving and contouring.

Managing the water table

Because the Wallace properties occupy an elevated dome it is not physically possible to keep a close control on the height of the water table. While winter water levels can be managed reasonably effectively by an effective drainage network, summer drying is less easy to control. Excessive soil drying in summer can have a significant effect on pasture production and encourage excessive peat shrinkage.

One of the best ways to prevent the water table dropping too much in the summer is to block secondary drains in late spring before they run dry (Environment Waikato, 1997). This can be done using sandbags or other water control structures. Such structures would need to isolate the water table for some distance either side of the drain to avoid bypass flow.

Water quality

Fifty years of peat management have honed their water table management and farm production skills, but the owners and managers at JD and RD Wallace Ltd are aware of the new challenge of reducing the impacts of intensive dairy farming on water quality and the potential for peat farms to have a significant negative impact on the health of water and waterways.

The Mangawhero Stream, which drains the northern side of the Moanatuatua Peat Dome and flows to the Waikato River, is monitored on a regular basis for water quality factors. Records show that the stream has very high phosphorus and nitrogen concentrations, well above safe contact recreational levels, and that bacterial contamination is extreme with *Enterococcus* levels averaging over 50 times higher than safe levels for swimming. The bacterial count makes the water unsuitable for livestock consumption. Records from 1993 to 1998 show a gradual deterioration in the stream in terms of nutrient concentrations and turbidity (the stream has a naturally high turbidity because of the tannins derived from peat), and a substantial (ten-fold) increase in bacterial contamination. The bacterial counts and the increasing trend are typical of many agricultural catchments throughout New Zealand.

Mangawhero Stream Condition Score: Contaminant Loading and Habitat Condition

Bacteria: VERY HIGH
probably due to surface runoff and stock accessing unfenced drains on some dairy farms

Nutrients: HIGH to VERY HIGH
phosphorus is likely to be entering drains in surface runoff, nitrogen levels are high due to intensive land use and substantial drainage

Sediment: MODERATE
difficult to determine in a stream with naturally high turbidity

Aquatic habitat: NOT DETERMINED
but likely to be poor because of the high nutrient counts which will induce excessive weed growth

Riparian habitat: NOT DETERMINED

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

The data does not allow us to determine whether the bacterial contamination is coming from cowshed effluent (point source discharge) from diffuse sources. However, the very high readings would suggest that a significant source may be cattle with free access to drains and surface water. Surface runoff during rain events would contribute some contamination but because the paddocks are relatively flat this is unlikely to be the predominant source.

Managing water quality

The Wallaces have all of their drains well fenced off from stock and manage their pastures so that water does not accumulate other than in drains. The likelihood of high bacterial contamination is therefore considerably reduced. Hump and hollow contouring is sometimes criticised because the hollows, to which cattle have access, can become waterlogged and lead to concentrated runoff containing sediment, fertiliser and faecal material. However, the Wallace farms maintain small grassy spinner ditches in their hollows to carry away any surface water. Cattle tend to step over these ditches rather than occupy them and any dung that happens to enter them is likely to be trapped by the grass in the spinner channel. Soluble nutrients are less likely to be trapped in this manner and will tend to move with any surface water flow.

Sediment loss, and therefore phosphorus loss, from the Wallace paddocks is minimised by careful grazing and pasture management. Well, but not excessively, drained paddocks and carefully monitored stocking rates and rotations maintain a healthy pasture sward throughout the year and reduce the exposure of bare soil. Drain bank erosion is minimal because of the exclusion of stock and the careful maintenance of drainage channels.

Nitrogen management is considerably more difficult on peat because of the need to drain substantial volumes of water from the paddocks and the propensity of nitrates (derived from urine and fertiliser) to leach rapidly through the soil to groundwater. The loss of nitrogen from dairy pastures has increased in recent times because of the trend towards increased nitrogen applications and the increased pasture growth that accrues. Terry Fear, General Manager of JD and RD Wallace, states that annual nitrogen applications on their farms have risen significantly over recent years in response to the obvious pasture production improvements. Now close to 200 kg of nitrogen per hectare is applied each year when less than 125 kg was applied only a few years ago. He is aware of the propensity of nitrates to be lost from the soil and has a policy of applying nitrogen in multiple 40 kg N/ha dressings to maximise uptake and reduce losses.

As is the case on many dairy farms, nitrogen fertiliser is applied through the autumn and winter months when grass growth is slow and nitrogen loss is likely to be highest (due to low plant uptake and high leaching). While pasture production may benefit, downstream water quality is the greater loser as a result of this practice.

Potential management options

The control and reduction of nitrogen loss from high intensity dairy farmland is a significant sustainable land and water management challenge. The reconstruction of strategically positioned grassy wetlands would be an effective method of extracting the nitrates (by denitrification) from the drainage waters. However, most peat properties have trouble enough removing excess water from their farms and are unlikely to have obvious depressions or wetland sites that would not create a backup of water onto farm paddocks.

Several studies (see Whangamata Stream, *Case Study 4*) have shown that aquatic and semi-aquatic weeds have the capacity to remove substantial volumes of nitrogen and phosphorus from flowing water. Semi-aquatic weeds growing along drain banks can be expected to function in the same way, so it may be an option to manage the weed growth in drains to levels that maximise nutrient extraction but do not result in clogging or excessive water backup. This could perhaps be most practical, and certainly most effective, in paddock drains and spinner ditches, where the volume of water is small and flooding less of a risk. Alternative drain maintenance techniques (aquatic weed clippers!) to the conventional mechanised drain cleaners and herbicides may have to be developed so that thick, cropped weed swards are maintained through 12 months of the year.

Loch Carron Farm, Meremere

Peter Buckley farms 103 ha on the edge of the internationally renowned Whangamarino Wetland north of Huntly. Much of the peat area of Peter’s farm is only one metre above sea level and is about two metres lower than the neighbouring Whangamarino Wetland.

Peter has produced 1000 kg/ha milksolids over recent seasons and maintains the productivity of his farm by carefully controlling the height of the water table. Drainage on the farm is controlled entirely by pumps on the edge of the wetland. Peter deliberately elevates the water table in the summer to maintain pasture production and minimise shrinkage and lowers it in winter to prevent soil saturation and pasture damage from stock. The incentive to minimise peat shrinkage is strong as already high pumping costs would increase if the farm was to sink any further.

Peter has fenced off all his drains on both sides and has well maintained shelter belts along some. When the shelter belts are on the northern side of the drain he has noticed that weed growth within the drain is reduced, probably because of the shading effect.

Photograph 31: Well fenced drain on Peter Buckley's property. Peter has planted shelter trees along the northern side of some of his drains which has reduced the amount of nuisance weed growth within the drains, probably as a result of the shade provided.

Peter owns a portion of wetland that adjoins Whangamarino and manages the vegetation to encourage native and exotic wildlife. Fernbirds and Australian bittern are occasional visitors and the native pukeko is often present in numbers that exceed the size of his herd.

Photograph 32: Peter has managed an area of privately owned wetland adjacent to the internationally renowned Whangamarino wetland to enhance its value as habitat for wildlife.

Summary of water management recommendations for peat

- Keep cattle out of all drains and areas of open water and saturated soil.
- Where possible elevate the water table during summer months to reduce peat shrinkage.
- Minimise peat shrinkage by cultivating only when necessary, or use no-till methods where practical.
- Apply fertiliser in small, multiple dressings and avoid the use of nitrogen fertiliser during the slow growth winter months.
- Maintain a healthy pasture cover throughout the year to minimise sediment loss.
- Do not deepen drains during maintenance. This can lead to over-drainage, affecting pasture production.

- Reduce the use of machinery for drain clearance. This can be significant source of sediment loss.
- Where practical, maintain a vegetation cover on and in paddock drains and spinner ditches which could function as a filter to sediment, dung and nutrients.

Case Study 6: Deer farming and riparian management in Southland

Deer can cause more damage to waterways than any other farm animal. Provided with access to streams, wetlands, drains, ponds, seepage zones, leaking water troughs or just saturated soil deer herds can quickly convert soil and vegetation to a muddy bog. Even on relatively dry land, paddocks occupied by deer are characterised by well-worn trails around the fenceline and, on slopes, by pasture-less dust pads mid-slope or at vantage points where the herds tend to congregate.

Trevor Manson and Neville Cunningham farm deer in Southland and have introduced farm and stock management practices to reduce the impact of deer on soil and water. Their experiences and ideas are described below.

Understanding the problem

Deer and deer farms do not produce the intensive loads of dung and urine that can be expected from dairy cattle, but in many other ways the impact of deer on waterways can be as great or greater. High sediment loads resulting from deer induced erosion is probably the greatest cause of water contamination. This can arise from the following situations:

- Deer with free access to streams will trample the stream margins, remove vegetative cover and destabilise steeper banks.
- Herds of deer habitually trample wet areas such as swamps, seepage zones, springs and areas of trough overflow or water leaks, creating muddy bogs. These wet areas are frequently in the path of surface runoff where the exposed sediment is likely to be quickly carried to stream or drain.
- Deer will churn up and pug saturated soils, destroying pasture and exposing soil to sheet erosion. This will often happen on steeper slopes and once the pasture has been destroyed the deer will maintain these “pits” through 12 months of the year.

Photograph 33: This winter spring-fed depression has been cut out by deer and now generates a substantial sediment load each winter. On this Waikato property a wide (80–100 metre) grassy, permanently fenced riparian margin with thinned blackwoods above effectively traps most of the sediment, although in heavy rain the sediment load reaching the adjacent stream is significant.

- Deer frequently congregate in corners, accessways and gateways, causing extensive trampling damage.
- Deer, particularly red deer, deliberately create muddy wallows during the rut and in late spring when they are shedding their winter coats. They cake mud onto their hides to assist them to scratch off their winter coats, and at other times of the year mud is used to eliminate biting insects and irritations.

Damage of this nature can be substantial – it can be extensive in area and significant in terms of its impact on pastures and waterways.

Photograph 34: Deer can cause extensive pasture damage and promote soil erosion when they are given access to waterways, saturated soils, springs and other areas where water accumulates. *(Photograph supplied by the Southern Regional Council.)*

Deer with direct access to streams will also be a direct source of faecal bacteria and nutrients to the stream water, and will cause extensive damage to most vegetation growing on riparian margins.

Measures to overcome the deleterious actions of deer must either counter their behavioural traits, isolate them from sites where damage can be caused, or remove the conditions that predispose them to cause soil damage.

Managing the problem

Trevor Manson

Trevor owns 200 acres (81 ha) of Southland flats north of Invercargill and 18 months ago (in 1999) he converted the property to deer where he now runs 400 red deer hinds, 150 yearlings and 13 stags. All of the previous fences were removed and new fencelines and races created to suit the movement and management of deer.

With considerable technical assistance from the Southland Regional Council, Trevor has permanently fenced out all drains and streams running through his property. The retired strips extend at least 5 metres each side of each stream or drain and rank grass provides an effective filter to surface runoff. Shelter trees (hybrid willows, poplars and eucalypts) have been planted along one side of many of the fenced off areas. The streams (now effectively straightened drains), are mostly fed by springs. Winter soils tend to become saturated and the resultant surface runoff can contain elevated concentrations of nutrients, faeces and sediment. The grassy filter strips operate very effectively at intercepting the surface runoff and encouraging the settling out of the suspended solids.

Photograph 35: A wide, well-fenced riparian filter strip on Trevor Manson's farm in Southland. One side has been planted with a row of tree seedlings for timber and shelter. Note the in-channel weed infestation. While the weed may promote some flooding, it serves well to strip the water of nutrients during summer in particular. This channel has the appearance of a drain, but as is typical of many parts of lowland New Zealand, this is a naturally occurring stream that has been stripped of its riparian vegetation and straightened to expedite water flow.

Trevor has also fenced out a corner of his property that was awkward for stock movement. A pond and trees have been established in this zone.

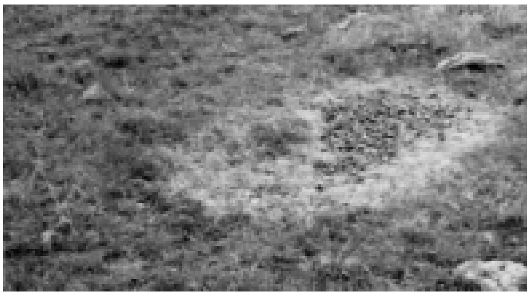
Some Southland soils, especially those with clay pans, become very wet during winter months. To reduce the damage caused to his pastures Trevor is constructing a wintering pad for his stock where up to 250 animals will be able to be held and fed for the wettest periods of the year. Wintering pads are becoming increasingly popular amongst deer and dairy farmers throughout New Zealand, especially those farming heavier soils. Provided the effluent generated by stock on the pad is well managed, wintering pads are a good option in terms of preserving soil and pasture condition and reducing soil and contaminant loss in surface runoff.

Neville and Sandra Cunningham, Taringatura Park, Winton

Neville Cunningham has been in the business of deer farming since the days when wild caught deer were the principal source of stock for the fledgling deer farming industry. He states that it has taken him many years of deer farming to fully understand the behavioural patterns of deer and how some of their less productive habits can be overcome.

Neville is convinced that much of the soil and water damage caused by deer is often a result of overstocking and poor stock management. He believes that short, intense rotations reduce the pacing behaviour of deer with a subsequent reduction in tracking along fencelines and other pasture damage. He is also aware that the removal of areas of water and saturated soils from access to deer will greatly reduce the potential for problems to occur.

On an area of newly acquired land Neville has taken several measures to reduce the opportunities for deer to destroy pasture and damage drainage channels. He has created 30 metre wide races running parallel to his drains. The races are entirely in pasture and are used as stock accessways and for controlled summer grazing. The drains are not fenced off from the races but on the opposing side of the drain he has established 3 metre wide shelter belts which are fenced on both sides. The paddocks have been well drained: subsurface tile drains and drainage sumps (soakholes) have been established at low points inside the race to catch and drain surface flow from the paddocks and prevent deer wallowing in wet patches. These measures are innovative and reflect Neville's concern for the damage deer can cause and the impact that they can have on farm production and the environment.

Photographs 36 and 37: Neville Cunningham is experimenting with 30 metre wide races on his deer farm near Winton. A double fence on the left of the drain/stream (on the left of the picture) protects a tree row. Neville's intention is to use the race for short-term grazing. Gravel-filled soakage pits such as that shown below are located in the race to collect and channel away surface runoff before it can accumulate.

While these ideas are well suited to Neville's system of farm management, they may not work for all deer farmers. Care would need to be taken to ensure that stock did not remain in the race area too long because the unfenced drain could quickly become the target of restless animals. A modification of Neville's race would have the drain included inside the fenced off shelterbelt so that deer could not access the drain and a grass sward could develop to intercept surface runoff.

Cost-benefit analysis

The Southland Regional Council provides technical and funding assistance to landowners who wish to undertake riparian works which are designed to mitigate and minimise streambank erosion and water quality problems, or to improve instream and riparian habitat. Riparian works including fencing, plant purchase, weed and pest control, release spraying and labour (up to $2000) are all eligible for a subsidy of 25 percent. The Council also provides financial assistance for erosion control works. Several regional councils provide funding assistance for riparian and erosion control works and most provide free technical support.

The damage caused by deer to pastures, soil and waterways can be as destructive to farm productivity as it is to the environment and water quality. Areas stripped of pasture and exposed by deer rarely recover without being re-cultivated and re-established in grass, and often on hill-country topsoil needs to be returned to the damaged areas before grass will flourish. It is, therefore, in the interests of all deer farmers to manage their stock and pastures in ways that minimise the likelihood of extensive damage.

Summary of management practices to reduce the impact of deer

The potential impacts of deer on water quality can be reduced by:

- permanently fencing all deer from streams, lakes, drains, swamps, ponds and riparian margins (including stream banks)
- excluding deer from areas that are periodically wet (saturated soils, surface drainage areas, etc.)
- excluding deer from steep and erosion-prone land
- preventing overstocking and overgrazing
- providing clean trough water, shade, shelter and salt blocks for all stock.

Case Study 7: Whaingaroa Harbour Care: community initiative to restore a harbour and a fishery

The Whaingaroa (Raglan) Harbour Care Society was established in 1995 in response to concern expressed by a group of Raglan locals about the poor and deteriorating state of their harbour. Fred Litchwark, Fiona Edwards and Val Hollard teamed up and called a public meeting to discuss the issue. Sixty people turned up and at that same meeting an incorporated society was inaugurated. A committee was selected, including Fred, Fiona and Val, to run the society and the restoration of Raglan Harbour began in earnest.

Understanding the problem

The catchment of the Whaingaroa Harbour covers 525 km^2, and it lies on the west coast of the North Island at the same latitude as Hamilton. Over the last century indigenous vegetation has been cleared from more than half of the catchment and much of the land is used for pastoral farming (sheep and cattle) and plantation forestry.

The harbour itself is an enclosed harbour with a narrow exit to the sea and 220 km of edge. The waters of enclosed harbours of this nature do not mix and flush with tidal seawaters as well as more open harbours do, and consequently they are prone to becoming polluted if the incoming fresh waters contain contaminants.

Sediment and bacteria

The deforested steeper headwaters of the catchment are prone to erosion and considerable quantities of sediment are finding their way into the harbour. Streams in the catchment with a cover of indigenous forest generate about 45 t /km^2/yr of sediment (Environment Waikato, 1998). Research at the Whatawhata Research Farm indicates that when the forest cover is removed, as in pastoral catchments, about 230 t/km^2/yr of sediment are lost and carried down to the harbour. Stream monitoring of several streams feeding the head of the harbour support the view that excessive quantities of sediment are entering the harbour. Average water turbidity and clarity measures in three streams, Waingaro, Waitetuna, and Ohautira, are well in excess of what is considered satisfactory, and have been so since monitoring began in 1993.

Bacterial concentrations in the upper Whaingaroa Harbour have periodically been extreme, and this too is verified by stream monitoring data . The Ohauiti and Waitetuna streams have recorded average *Enterococcus* counts near or above 100/100 ml, when a reading of 33/100 ml is considered the maximum safe level for contact recreation (ie, swimming). Some readings during the year reached counts of 60,000/100 ml in the Ohauiti Stream and 520 in the Waitetuna. With bacterial counts as high as this in flowing streams, it is no surprise that levels as high or higher than this occur at the upper end of harbour where tidal mixing with fresh seawater is limited.

Bacterial levels of this magnitude pose a serious human health hazard. High sedimentation and bacterial contamination can have a significant impact on harbour shellfish and molluscs. Shellfish such as the cockle are filter feeders; excessive sediment can clog their filters and smother their feeding grounds. Decreased shellfish densities and changed invertebrate populations, as a result of high sediment levels, can have an impact right down the food chain so that fish and wading bird populations can be significantly affected. Fred Litchwark, as well as being a founder of the Whaingaroa Harbour Care Society, is also the local Fisheries Officer and he has noticed a significant decline in all aspects of the harbour fishery over the last decade. It is his concern for this that spurred the local initiative to do something about it. Shellfish also tend to ingest and accumulate bacteria which makes them unsafe for human consumption.

Bacterial counts as high as those recorded in the pastoral farm catchments are most likely to arise from faeces washed in surface runoff from pastures and livestock with direct access to streams, seepage zones and wetlands. The greatest levels of stream and harbour contamination are likely to occur following heavy rain when faecal material is washed by surface water from hillsides as well as from the riparian area.

Until recently, the harbour margins of many farms remained unfenced and cattle, in particular, had free access to the harbour mudflats. This obviously provided a direct source of faecal contamination to the harbour, and in addition, cattle grazed heavily on the harbour margin indigenous vegetation.

Nutrient inputs

Compared to the level of sediment and bacterial contamination, nutrient levels (nitrogen and phosphorus) are only marginally poorer than satisfactory. This probably reflects the steeper topography and therefore less intensive nature of agriculture in the catchment, although it is suspected that some of the more dairy oriented catchments may have higher nutrient outputs.

Whaingaroa Harbour Catchment Condition Score: Contaminant Loading and Habitat Condition

Bacteria: VERY HIGH
very high catchment inputs accentuated by poor mixing of water in the harbour

Nutrients: MODERATE to HIGH
phosphorus and nitrogen levels sometimes at levels that can cause nuisance weed growth

Sediment: HIGH to VERY HIGH
high sediment contamination as a result of soil erosion during heavy rain events

Aquatic habitat: POOR
harbour aquatic life substantially affected by high sediment loads and bacterial contamination

Riparian habitat: MODERATE to POOR
only patches of native bush and riparian vegetation remain in the catchment although more than many less steep catchments elsewhere

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

Managing the problem

Whaingaroa Harbour Care's goal is to improve the quality of the water entering the harbour and by doing this hopefully improve the overall ecological state of the harbour. The group has decided to focus on what it considers will produce the most substantial and rapid improvements to water quality: the retirement of the harbour edge and the riparian margins of tributary waterways, gullies and wetlands and the restoration of indigenous vegetation to those margins.

Fundraising

To pursue this goal Harbour Care needed funding and support to pay for the fencing and for the production of native plants. Effective publicity and shrewd politicking, plus some gentle leaning on people, has managed to raise close to $180,000 between mid 1995 and early 1999, from a wide variety of sources.

The Lottery Grants Board and Environment Waikato provided initial funding of about $60,000 to enable the group to construct a native plant nursery in the Wainui reserve near Raglan. Fred Litchwark manages the nursery and with the assistance of Community Taskforce workers (a work scheme of the former New Zealand Employment Service) and community volunteers over 100,000 native plants have been propagated, raised and planted in the Raglan area.

While the harbour initiative has been well funded to date, the committee is looking to set up the project over the next five years so that it can generate its own income and reduce its reliance on government handouts and voluntary contributions.

Selling the dream

Whaingaroa Harbour Care is somewhat unique in that it is a community initiative driven mostly by people who are not substantial landowners in the catchment. Its challenge was to get the landowners in the catchment on-side and have them buy into the dream of making Raglan Harbour a showcase to the world for environmentally sustainable farming.

Initial farmer reaction was decidedly cold to the plan to fence off streams and harbour margins on private land. To overcome the initial resistance and gain momentum with their initiative, Harbour Care approached pre-eminent landowners in the district to fence off their riparian areas in the hope that others would follow suit. This approach was largely successful and the situation has advanced from where farmers were approached to fence and plant their riparian margins to where Harbour Care are now being approached voluntarily and orders for plants now exceed what the nursery can supply. The committee's philosophy has always been to "work with landowners who want to work with us".

Community attitudes have advanced considerably as well, to the extent that a farmer who let his cattle graze an area of recently planted natives was dobbed in by the local school kids!

Fencing and planting

The Whaingaroa Harbour Care group focused their initial attentions on restoring the Wainui Stream which rises southeast of Raglan on Mt Karioi. This was a deliberate and tactical decision so that a completed example of a restored stream would be available as a demonstration site. Virtually the entire length of the Wainui stream to the harbour is now fenced and well established in native plants. The group has also revegetated a substantial area of coastal cliff reserve (Wainui Reserve) with native coastal species.

Photograph 38: The Wainui Stream now flows through a wide, revegetated riparian zone. Flax, cabbage tree and other native riparian species now occupy the land along its entire length. Five years ago it was grazed pasture to the water's edge.

Efforts now are being directed at fencing and planting harbour and stream margins elsewhere in the catchment. Environment Waikato provides funding for the purchase of fencing materials, Whaingaroa Harbour Care provides the plants and planters for free and landowners are required to construct the fencing. To date, more than 100,000 plants have been planted and over 100 km of fencing constructed.

Photograph 39: The retirement and planting initiative is now moving into the tributary streams and rivers that feed into the harbour. Here Fred Litchwark and his Community Taskforce workers plant a recently retired margin along the Waingaro River.

Photograph 40 Whaingaroa Harbour Care has also exerted its pressure on the local district council to improve its stormwater runoff. Here a gravel lined drain channels runoff through a grass and flax filter before the water enters the stream.

Riparian margin width

Fred and his team have tried to create riparian margins that are as wide as possible wherever they go. They are aware that while livestock will be excluded from streams with a fence any distance from the stream, to make a significant reduction in sediment and bacterial contamination from surface runoff a wide grassy filter strip is necessary. The steeper the land, the faster the surface runoff, and the wider the riparian filter needs to be. Fred has also been careful to fence round seepage zones and riparian wetlands, in recognition of their water cleansing capacity.

Species selection

Flax has been the basis of most of the riparian plantings so far. This is partly because it is easy to produce (from seed or by splitting parent bushes), but also because it is an excellent multifunctional native plant with a wide tolerance range. It is tolerant of temporary water submergence, partial burial in river sediment, waterlogged sites and dry soils, full sun, partial shade, exposure to wind and frost, acid soils and alkaline soils, high fertility and low fertility. It is generally not consumed by animal pests (although pukeko delight in extracting small seedlings) but it is eaten by cattle. It produces flowers after only a few years and these draw in native birds which in turn deposit seeds of other native species. And its spreading habit creates sheltered micro-sites in its lee for seed germination. Other species planted in the initial mix have been cabbage tree, manuka and karamu.

The primary aim with the initial round of planting is to establish a good cover of plant material. Later, interplanting will increase the diversity of species, and natural recruitment should assist diversity as well.

The committee has been very careful to source its plant material from the local district, and the need to collect seed in advance of propagation partly explains why the species diversity to date has been limited.

Weed control

There is no formal weed control or plant maintenance plan. Sites are cleared or grazed prior to planting but post-planting maintenance only occurs where plant mortality is high. Fred grows his plant stock to a tall grade (50 cm or more) before planting, and this seems to assist their survival in competition with pasture species where smaller grades may fail.

Monitoring the recovery and planning the future

The project is still very much in its early days and measurable improvements in water quality and stream and harbour life may not become apparent for several years. However, local observations of the Wainui Stream would suggest that stream life has already increased noticeably. It is hoped that a comprehensive monitoring programme can be developed that will track the restoration work undertaken and record the physical, chemical and biological changes that occur over time in the streams and the harbour.

One thing is for certain: there has been a definite attitude change in the wider community towards riparian management and the Whaingaroa Harbour Care Society. As Fred said, when a local cocky dropped in a crate at the nursery after a day of planting: “They thought we were nutters when we began – now they’re buying us beers”.

Case Study 8: Dairying on pumice: controlling erosion, willows and poplars

Volcanic pumice soils dominate a large area of farmland in the central North Island, and extend out from this central core along the major river channels like the fingers of a hand. The Waikato River trench and much of the land farmed on the river terraces along the length of the river have a substantial pumice base, derived from sediment carried and deposited by the river. The depth and extent of these alluvial pumice deposits is testament to the erosion prone nature of pumice when exposed to flowing water.

Understanding the problem

In the 1950s and early 1960s much of the land between Taupo and Rotorua was cleared of remaining bush and put under increasingly intense farming regimes. Dairy farming commenced on the more fertile soils in the Reporoa basin and every inch of land was converted to pasture. As a result of land clearance and development significant changes in runoff patterns occurred, from largely sub-surface flow to overland flow, and major soil erosion problems began to emerge throughout the area. The erosion took the following forms:

- Soil slip erosion – this reached severe proportions on some steeper properties where stock pressure, mainly in the form of cattle grazing, had removed the vegetative cover. This grazing rendered the land more susceptible to damage from storm events than in the undeveloped state.
- Severe gully erosion – many of the gully channels in the area are ephemeral waterways which tend only to carry water under storm conditions. They are usually wide and entrenched, and composed of beds of pumice infill materials which under high flow conditions are highly erodable.
- Bank erosion and siltation in perennial waterways – following a storm in 1967, the main Torepatutahi channel became a mobile bed of moving pumice over much of its length. A number of road bridges and culverts were destroyed, and it was estimated that a land area of 370 ha was severely eroded.

These events led to the preparation of the first catchment scheme for the Reporoa area, the Torepatutahi Catchment Control Scheme. Under this scheme it was recommended that major land use changes should occur, and an extensive soil conservation programme should be implemented.

The Torepatutahi Catchment Control Scheme

The Torepatutahi Scheme was approved for government funding by the Ministry of Works and Development in 1971, at a total cost of $165,647 (later updated to $224,313), attracting a grant of $3 for $1 on the capital programme and $1 for $2 on scheme maintenance.

The prime objectives of the scheme were:

- to control active soil erosion
- to provide protection to land with potential for future erosion.

It was proposed that in excess of 1000 ha of land be retired from pastoral use to provide protection to the major drainage systems. This land was to be planted in a range of exotic tree species. It was hoped that this would:

- reduce the magnitude of peak runoff from minor and moderate storm events
- increase the infiltration within the bed materials as opposed to across the surface of these waterways
- control erosion of channel beds and stream banks.

In the downstream reaches of the major catchments, the planting of riparian margins was proposed to reduce bank erosion and to protect adjacent productive land.

Photograph 41: Government-funded catchment schemes led to substantial riparian retirement and revegetation in the 1970s and this has greatly reduced the levels of erosion and sediment transport. Reporoa Basin rivers such as the Torepatutahi are now protected by extensive plantings of willow in the channel and exotic timber species on the flanks.

Managing the problem

Fencing and planting

The capital works for the scheme were completed in 1976 with 167 km of retirement fencing constructed on 40 properties and 600 ha of conservation area created behind those fences.

Most of the retired areas were planted in exotic tree species.

Thirty-eight percent of the sites were planted in *Pinus radiata* and 20 percent in poplars. The remaining areas consist of regenerating native vegetation. Willows and poplars were favoured in the most severely eroding sites because of their ease of establishment, extensive fibrous root systems and rapid growth. The success in controlling the extreme erosion problem in the catchment is considered to be attributable to the use of these species.

Some of the willow and poplar plantings are now showing signs of senescence (due to leaf rust) and are collapsing onto fences and congesting stream channels. The willow and poplar stands have remained largely untended which has accentuated the degree of stand degradation. Booth willows have proved to be the most short-lived and are now causing the greatest problems, collapsing and blocking channels. Their removal will be required in several areas to reduce the likelihood of flooding and increased bank erosion.

Of the total conifer plantings, 51 percent have undergone silviculture.

Land Improvement Agreements

A Land Improvement Agreement (LIA) was entered into with each property landowner at the time of works commencement and each is registered against the land title.

The primary obligations of the property owner under an LIA are to:

- carry out routine repairs and maintenance according to the provisions of the agreement
- keep fences in a stock proof condition
- maintain conservation areas free of stock
- carry out silviculture in order to maintain trees in effective condition
- make application for approval to utilise mature trees
- replace utilised (harvested) trees at owners' expense.

Ian McGillivray

Ian McGillivray has farmed in the Reporoa area since 1968. He has owned his current 133 ha farm, alongside the Torepatutahi Stream, since 1989 and now produces 1100 kg/ha of milk solids per annum from his 420 jersey cow herd. The entrenched portion of the stream adjacent to Ian's farm is known as the Torepatutahi Canyon and it is considered to be a world class trout fishing stream largely because of the clean spring fed waters that flow down the canyon to the Waikato River.

Ian recalls the extensive erosion in the region in the 1960s and 1970s and was one of the first in the local area to plant trees for bank and channel stabilisation. Much of the erosion and sediment loss has now been controlled by these efforts but a new series of water management problems are now requiring attention. Ian is a member of the Torepatutahi landcare group which has been set up to enhance the canyon and improve land and water management in the district. He is also a member of a local watchdog group set up to provide independent monitoring of the catchment scheme.

Maintaining the riparian plantings

The stream margins on Ian's property are now all permanently retired and well established in trees. The exclusion of stock and the stabilisation of the stream banks with willows and poplars has greatly reduced erosion, producing a stream that has good clarity and low levels of sedimentation.

Booth willows and poplars are now collapsing in the stream channel and clogging the water flow; their removal is important to reduce the likelihood of flooding and increased bank erosion. Environment Waikato offers a two-for-one subsidy for the clearance of problem willows as they do for catchment fencing and retirement planting; the problem is that it costs $10,000 per kilometre to clear the willows and there are many kilometres of the original plantings to clear. The one-third contribution to be provided by the farmers would amount to a cost of $50,000 for one farmer in the catchment with a large area of plantings. The high cost is because the trees must be cut and all material removed to avoid vegetative regrowth. The trees can't be pulled by the roots because of the soil disturbance that would result. Local farmers and Environment Waikato have investigated the market for poplar timber in the hope that the extraction of the Italian poplar component of the plantings may reap some return. However, the current export market pays little more than $\$50/m^3$ delivered to the port which barely covers the cost of felling and transport.

Photograph 42: While the initial willow and poplar performed well to stop much of the in-channel erosion, they are now the cause of some problems. Some of the plantings are now showing signs of senescence and are collapsing onto fences and congesting stream channels. Their removal will require considerable effort and expense.

Water and soil monitoring

The intensification of dairy farming and the expansion of dairying to the margins of the Reporoa basin have placed increased pressures on stream health and water quality. Out of concern for the health of the Torepatutahi, Ian and his landcare group members sought the assistance of Environment Waikato to monitor the stream water quality. Ian has gone further and now supports an Environment Waikato trial on his property that is designed to measure the impacts of different farm practices, such as irrigation and effluent application, on nutrient levels and movement in shallow groundwater beneath his farm pastures.

Water monitoring data shows that the Torepatutahi has excellent clarity, rating as one of the better streams in the Waikato River, and other measures, including nitrogen, pH, water temperature and dissolved oxygen, all indicate a healthy stream. The one exception is a very high phosphorus reading in the stream water, averaging nearly three times higher than minimum levels that can cause nuisance aquatic plant growth. No bacterial readings have been recorded in this stream although adjacent catchments draining dairy farmland are registering bacterial levels in excess of those safe for recreational use. From this information it would seem that phosphorus is still being lost from pasture in excessive concentrations, probably being carried in surface runoff attached to sediment particles, although it is important to note that phosphorus levels tend to be naturally high in streams draining volcanic soils.

Torepatutahi Condition Score: Contaminant Loading and Habitat Condition

Bacteria: UNKNOWN

Nutrients:
Phosphorus HIGH
perhaps due to surface runoff, and the loss of a grassy filter strip along riparian margins as trees have grown.
Nitrogen MODERATE

Sediment: GOOD – IMPROVED
considerably less streambank erosion as a result of riparian retirement and planting

Aquatic habitat: GOOD
despite high phosphorus levels weed growth is not excessive; temperature, clarity and shade are good because of riparian planting

Riparian habitat: FAIR and IMPROVING
regeneration of native plant species is starting to occur naturally to complement the limited array of tree species planted

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

Land-based effluent application

The recent encouragement for dairy farmers to apply cowshed effluent back on to pastures ("land-based application") rather than manage it in traditional settling ponds, while designed to lessen the contamination of waterways, could become a threat to water quality on light pumice soils if care isn't practiced. Environment Waikato restricts the annual applications of effluent to a maximum nitrogen loading of 150 kg/ha, but there have been observed cases where faulty machinery (such as burst pipes) or poor management (positioning irrigators on ridge tops) have resulted in excessive volumes of water and effluent being applied to the extent that surface runoff has occurred. Surface runoff generated from poorly managed spray application of effluent will carry substantial concentrations of phosphorus, pathogens and ammonia (NH_3). The nitrates in effluent leach readily, and especially on free draining soils such as pumice, so excessive effluent application is likely to contaminate groundwater.

Land-based spray application of effluent should be carefully applied and fertiliser applications reduced correspondingly.

Dairy farming often has the finger pointed at it because of its negative impact on water quality. The recent expansion of dairy farming onto the plateau at the head of the Torepatutahi has resulted in what Ian McGillivray says is a noticeable reduction in peak flows during heavy rain. The reasoning is that the pastures maintained by dairy farmers are longer and more lush than those managed by the previous sheep farmers and so act as better filters to surface runoff, slowing down the speed of water and prolonging its discharge to the stream.

Ian has continued to supplement his riparian plantings with ornamental trees and shrubs. Few native species have been planted to date because of the extremely harsh winter conditions in the Reporoa basin and the consequent low survival rates of all but a few native species. It is interesting, however, to note that after 30 years of establishing an exotic tree cover along the riparian margins, native species are now beginning to establish naturally, brought in by birds (as seed) and wind. Kohuhu, cabbage tree, tree ferns, karamu and koromiko can now be seen under the exotic tree canopy.

Photograph 43: Fifteen to 20 years after the streams were retired and planted in exotic tree species, native shrub and tree species are now gradually starting to appear under the willow canopies. The Reporoa Basin experiences very hard frosts and many attempts to establish native seedlings in the open have failed. The more open canopies of the senescing willows appear to provide favourable habitat for native colonising species.

Ian and Elizabeth McGillivray have taken the attitude that the Torepatutahi Stream arrives at their property in near-pristine condition and they want to do what they can to ensure that it leaves that way.

Case Study 9: Orcharding and sustainable land and water management in Eves Valley, Nelson

Philip Kempthorne produces apples for export on his Eves Valley property at the base of the Moutere Hills near Nelson. He calls himself an orchardist although in addition to the 36 acres (15 ha) he has under orchard he has 130 acres (53 ha) of pine trees, 15 acres (6 ha) of protected native bush, and 150 acres (61 ha) of pasture on which he runs 350 ewes, 120 replacements and 20 cattle.

His property lies on flat river terraces and rolls to steep hills on both sides of the Eves Valley Stream, and runoff from his land feeds that stream.

Photograph 44: Looking up Eves Valley to Philip Kempthorne's apple orchard on the river flats and gentle slopes in the middle ground. Some of the pine forestry on the left belongs to Philip and his father. This property provides a good example of appropriate landuse.

Philip produces apples largely for the North American market, which, while generally being more lucrative than the European market, has more stringent conditions relating to the quality of fruit, especially in terms of the freedom of the produce from insect and fungal pests and pest damage. Until recently the American market required that apples be treated with a selection of organophosphate pesticides as a condition of their importation. This is contrary to the situation in Europe where markets are increasingly demanding chemical residue free and sustainably produced food.

Understanding the problem

Orcharding potentially offers the following threats to water quality:

- contamination of groundwater with pesticides by leaching
- pesticide contamination of waterways by spray drift
- nitrogen contamination of groundwater by leaching, with the assistance of applied irrigation water
- fertiliser contamination in surface runoff
- processing contaminants in outwash from fruit packing sheds.

Pesticides

Pesticides, especially insecticides and fungicides, are an essential part of the orcharding industry enabling it to meet stringent international fruit quality specifications.

Black spot (apple scab) and powdery mildew are the most prevalent fungal diseases affecting apples, and fire blight, although not a commonly occurring disease on well-managed orchards, is used as a trade barrier to exports.

Leafroller and mealy bug are the most prevalent insect pests in apple orchards.

Traditional spray programmes in the past used large volumes of toxic organophosphates as a preventative measure of pest and disease control. These chemicals were generally less specific in their activity and more persistent in the environment than many of the more recent chemicals. Increasing international market and consumer pressure has lead to the reduced use of organophosphates and more restrained usage of more crop specific new generation chemicals that have a lower environmental persistence.

Pesticide residues have been detected in recent times in groundwater in various parts of New Zealand, more so beneath areas of intensive cropping (especially maize) and intensive horticulture (including orcharding) (Smith et al, 1993; MAF, 1993/10). While these recorded concentrations have been below criteria for drinking-water they are cause for some concern. Research studies have also recorded the presence of some widely used herbicides in measurable concentrations in streams following surface runoff events (which could include heavy rain or irrigation). Although they did not persist in the stream water for long there is potential for harm to be caused to instream plant and animal life.

Fertiliser

Philip applies 150 kg of a superphosphate mix per hectare to his orchard and an autumn dressing of 150 kg/ha of CAN (compound ammonia nitrogen). Young and weak trees will get an additional 100 kg/ha in spring. The fertiliser is applied as a band along each tree row to avoid wastage between rows. Soil tests are carried out annually and foliage analysis at regular intervals.

The rates of fertiliser being applied are well within the plants' capacity to utilise it, although the concentrated nature of the band application does lend itself to loss in surface runoff and, for the CAN, loss due to leaching. The applications in spring and autumn do avoid the period of irrigation when leaching and runoff could occur.

Irrigation

Philip uses a drip irrigation system in his orchard over the summer and applies the water up to a maximum rate of 50–60 litres per tree per day leading up to harvest. The drip system is the most efficient in terms of water utilisation and applies water only to the soil above each trees root system.

It is important with this system to match the amount of water applied with the needs of the tree. Otherwise excess water may be lost to groundwater and nitrate fertiliser may well be leached with the water.

Managing the problem

Philip has implemented several sensible land and water management practices to improve the sustainability of his operation, several of which have originated from a New Zealand-wide initiative.

ENZA IFP programme

ENZA (the New Zealand Apple and Pear Marketing Board) is introducing a scheme called the Integrated Fruit Production programme (IFP) which has been developed to improve the sustainability of orchard production in New Zealand, and to meet the increasing international consumer demand for improved food safety and increased environmental responsibility. The programme is a voluntary one and aims to supply growers with knowledge and tools to better manage the inputs to orchard production and reduce the impacts on the environment.

The programme was started in 1997 with an initial focus on pest and disease control and the reduction and more justifiable use of pesticides on orchards. Several more modules are planned to be introduced in 2000 including water, weed and soil management modules. Fifty percent of New Zealand orchardists now participate in the ENZA IFP scheme and this is expected to increase to 75–85 percent this year. Philip Kempthorne is one of those participating.

The pest and disease module encourages growers to apply agrichemicals on a justifiable basis and to reduce residue. That is, chemicals need not be applied until they are needed and then only in the quantities necessary to perform a function. There are three approaches or tools available to growers to determine justifiable use:

- insect/disease monitoring equipment and supporting information: for example, when leafroller numbers trapped exceed a certain prescribed threshold the application of insecticide is justified to prevent likely crop damage
- a phenology-based approach where growers are schooled in the stages of insect or fungus lifecycles or tissue growth that are most vulnerable to chemical control
- an early warning or predictive system, where the onset of certain conditions, especially weather conditions, can be used as an indicator of the likelihood of a pest or disease problem.

ENZA supplies growers with the information and tools necessary for them to carry out these measurements.

To participate in this module growers are required to submit their spray diaries twice yearly and the information in them is screened for compliance in the chemical products used, rates of application, intervals between applications and adherence to withholding periods leading up to harvest. Occasional random audits occur in addition to monitor compliance.

The soon to be released water management module emphasises the responsible use of water on orchards and provides the tools and understanding of processes for growers to do water budgeting to determine when their crops need water and how much is required. Crop and Food Research is developing a kit for the ENZA IFP programme that will enable growers to determine crop water deficit levels.

The weed management module focuses on the use of residual herbicides and promotes non-chemical weed management methods.

The soil management module emphasises the need to justify fertiliser use. Regular soil testing complemented by foliage testing is advocated to determine fertiliser requirements, and ENZA is developing a kit to enable growers to determine aspects of soil health including worm counts, other biological indicators and soil compaction.

There are no market premiums offered by ENZA or the international markets to growers who comply with the IFP programme; however, ENZA has offered an incentive of 25 cents per carton for growers to join the programme. This incentive will cease soon now that more than 50 percent of growers participate in IFP and may in future be replaced by a penalty for those not complying.

There are no international markets that require IFP compliance as a condition of supply, but this has more to do with the fact that ENZA has managed to achieve such a high level of compliance amongst its growers. If, for any reason, ENZA ceased the IFP programme it is likely that many of its European markets would request its return.

The fact that ENZA has managed to achieve such a high and rapid level of grower support for a new concept that promises no increase in grower return and has a strong environmental emphasis is something of a revelation. The ENZA IFP manager, Graham Hull, puts it down to the development of a good network base and taking time to deal to the perceived risks held by growers. The first 10 percent of growers who joined the programme are described by Graham as those with a real vision for sustainable orchard production and marketing in New Zealand. ENZA worked with this group to test the system and disseminate the ideas to other growers. The next 40 percent of growers are genuinely motivated to improve the environmental soundness of their operations, whereas the remaining 50 percent are less motivated and are taking more time to make the change. ENZA has 75 staff (“facilitators”) in the field working directly with growers and assisting remaining growers to see the practical benefits in the IFP programme.

Disregarding any future marketing benefits that might accrue from IFP, and the obvious environmental improvements that will result through reduced chemical and nutrient pollution of soil and water and more sustainable water utilisation, the programme offers the potential for substantial savings for growers, especially in the form of reduced agrichemical, fertiliser and water usage costs. The programme has already shown in three years of operation in New Zealand that fruit quality is at least as good if not better than that produced with conventional management.

Appropriate land use

In addition to the orchard-specific sustainable land and water management practices espoused by ENZA, Philip has applied aspects of sustainable and sensible land and water management to his property as a whole. Sheep are run to complement orchard management, where they can be used as a cheap means of grass and weed control in the orchard, and they are productive on the steeper land where orcharding is not feasible. Pine plantations occupy the heads of the valleys and function to intercept rainfall and reduce runoff through the farm to the stream.

Summary of good orchard management practices that will minimise impacts on water quality and riparian and instream habitat

Pesticide use

- Minimise the need for pesticide applications by applying them only when needed, at times when they are most likely to be effective and in recommended concentrations.
- Use new generation chemicals wherever possible, that have a high degree of target specificity, have low persistence in the environment and are less inclined to be leached to groundwater or carried in surface runoff.
- Apply chemicals in conditions and with equipment that prevents spray drift and coverage of non-target plants and waterways.
- Avoid, whenever possible, applying chemicals immediately prior to rain.
- Investigate alternative methods to the use of herbicides for the control of weeds and unwanted grass in the orchard.

Fertiliser use

- Apply only as much fertiliser as the crop can utilise.
- Use soil testing and foliage analysis to determine crop fertiliser needs.
- Apply fertiliser in split dressings to maximise plant utilisation and minimise losses to groundwater and streams.
- Whenever possible avoid applying fertiliser immediately prior to rain, on saturated soils and during winter months when plants are not growing.

Photograph 45: Across-contour tree rows and the application of heavy fertiliser dressings on the ground beneath the trees increases the risk of fertiliser loss by surface runoff and subsequent contamination of stream water. Pesticides may also be carried to streams by surface runoff. With-contour tree rows and grass filter strips along stream margins can reduce the likelihood of water contamination.

Water usage

- Avoid excess water applications that could lead to surface runoff.
- Apply water at times and at rates equal to the crops' needs.

Land and vegetation management

- Maintain a sizeable buffer zone between the orchard edge and any stream, pond, lake or wetland, and maintain a thick cover of grasses or sedges in that zone to serve as a filter for water, fertiliser, sediment and pesticide runoff.
- Maintain a healthy grass sward between tree rows and at the end of them, as a filter.
- Avoid excessive soil compaction that could promote surface runoff.

Case Study 10: Riparian habitat restoration on the Mangahanene

The Mangahanene Stream is a small stream on the northern side of Lake Karapiro draining a rolling hill catchment of approximately 1500 ha. The catchment is largely in pasture and sheep, cattle, and deer are farmed.

David Wallace and Juliette Chamberlain own the land, called Warrenheip, alongside the lower reaches of the stream before it flows under State Highway 1 and into Lake Karapiro. Twelve hectares of their small drystock farm consists of an incised riparian valley through which the Mangahanene flows. The valley has become incised over the last portion of its length because it passes through deep, erosion prone alluvial pumice deposited from the Waikato River. The valley bottom, while deep, is also sufficiently wide to accommodate the stream and small stream terraces.

David and Juliette have a vision to restore their riparian valley to something like its pre-human past, and have set themselves the task of not only re-establishing the indigenous vegetation but restoring the riparian ecosystem to as functional and self-sustaining a state as possible. Their short term (5–7 year) plan is to remove the exotic plants and establish a complete indigenous plant cover, and to rid the valley of vertebrate pests. The medium-term plan is to encourage a diversity of native birds and other vertebrate and invertebrate wildlife to migrate naturally to the valley and for others to use it as a safe migration corridor, and to return the stream back to reasonable health (with the assistance of upstream neighbours); and the long-term plan is to see the valley ecosystem evolve naturally and perhaps be a home for some of New Zealand's more rare wildlife.

This restoration project is an unusually large one to be undertaken by private individuals, but the messages and experiences conveyed in this case study are relevant to all native restoration projects irrespective of size.

Understanding the problem and accepting the challenge

Exotic influences

Vegetation

In 1996 David and Juliette's portion of the Mangahanene contained very few indigenous plant species. Much of the wetter portions of the valley floor comprised impenetrable stands of grey and crack willow and the middle and upper slopes had a cover of scattered old-man pines, pockets of mature Tasmanian blackwood and black locust and rapidly spreading infestations of seedlings of both of these two species. Pampas and pockets of gorse occupied the exposed pumice ridges and blackberry filled many of the remaining spaces on wet and dry land.

Approximately one-third of the valley slopes retained a mature kanuka canopy and small pockets of tree ferns existed in amongst the willows and black locusts. The only other native species of any consequence were karamu, mingimingi, koromiko, and mahoe with some pate in the wetter, more sheltered portions of the valley bottom.

One immature rimu is all that gives an indication of what once would have been a dense riparian forest with a canopy of rimu, totara, kahikatea and matai. A couple of native logs, possibly totara, and some remnant logging equipment which lie on the valley bottom are the only other signs of past vegetation.

Photograph 46: Much of the valley floor was covered with willow and old man pine trees. The willows were cut, stacked and burned. The pines were felled, cut into segments and left to rot on the forest floor, providing much needed organic matter to the soil.

The stream and its inhabitants

The Mangahanene is a typical pasture stream. Flood flows rise and fall rapidly and considerable volumes of silt pass downstream into Lake Karapiro with each high flow. The sections where pasture has grown to the stream edge have unstable, loosely packed pumice banks which are easily undercut during high flows.

The stream is home to eels and, surprisingly, significant populations of kaakahi (freshwater mussels) and koura (freshwater crayfish). The mussels and crayfish are present despite the high sediment loads; the reason possibly being that pumice sediment is more coarse than that from clay and may not clog the filters of these animals to the same extent that clay does. While eels and other migratory fish can conceivably migrate downstream, they or their offspring cannot return because of the Karapiro hydro dam and a 2 metre high elevated culvert that carries the Mangahanene waters to Lake Karapiro. Artificial structures to enable fish passage will have to be built before several of our native fish species can be expected to naturally inhabit the Mangahanene Stream.

Several years of retirement from livestock have not resulted in any significant growths of aquatic weeds within the stream, even during periods of summer low flow and on open, unshaded reaches of the stream. This would suggest that the level of nutrients entering the stream from farmland further up the catchment is not excessively high. A privately organised stream monitoring programme will take water quality readings over several years at several sites along the stream and this will help determine what the inputs are and what of those inputs require active management.

Despite the extent of the planned riparian restoration it is unlikely that there will be any significant improvement in water quality and instream habitat until landowners upstream reduce the inputs of sediment and nutrients.

Terrestrial wildlife

Pukeko and fantail are the only resident indigenous wildlife of any note. The lack of any diversity in plant species is likely to be the reason for the absence of indicator bird species such as the tui, bellbird and kereru. It is expected that they will be enticed to the valley from nearby pockets of bush when the planted native trees and shrubs begin to flower and fruit.

Animal pests

Possums, rabbits, hares, cats, rats, mice and possibly ferrets and stoats are present in the valley or around its perimeter. Possums, rabbits and hares offer the greatest initial risk because of their liking for freshly planted native seedlings. Cats, stoats, ferrets and rats will threaten at later stages when birds begin to breed in the valley. Rats and mice are voracious consumers of native seed, especially the seed of our native conifers (including rimu, totara, and kahikatea). Their early control is advisable to allow seed carried into the valley by birds to have a chance to germinate and grow.

Proximity of indigenous influences

The speed with which natural plant succession can occur in the valley is a function of:

- the availability of a diversity of suitable micro-habitats in the restoration area
- the proximity of areas of native vegetation containing a diversity of later successional species
- a means by which seed dispersal can occur.

Where there is a lack of diverse native bush within a few kilometres of the restoration site continued planting may be the only way to introduce secondary and advanced successional plant species. Some native tree species with large seed, such as tawa and karaka, rely almost exclusively on the native kereru to disperse the seed to new sites. In the absence of kereru, which is the case over large areas of New Zealand farmland, tawa has no natural means of dispersal and must instead be planted.

David and Juliette’s Karapiro property has several native reserves within a few kilometres of it, and a variety of seed dispersers such as the kereru occupy those reserves. Their challenge is to provide the incentive for those seed carriers to visit their valley and create the conditions that will encourage the germination of the variety of seeds that will be deposited.

Managing the restoration

The plan

David and Juliette's plan was to establish a complete cover of indigenous colonising plants over their entire valley within five years. This exercise was broken into four stages:

1. Removal of all of the exotic trees and shrubs from the valley with the exception of a few that provided some essential cover or were performing a vital erosion control function.
2. Immediate planting of native seedlings over all open and exposed sites at sufficiently close spacings to reduce the likelihood of problem weed species establishing within 3–4 years of planting.
3. Thorough and repeated releasing of all planted seedlings from competition from weeds for at least three years after planting.
4. Planting secondary native tree and shrub species and some later successional and climax species in areas where there is existing vegetative cover or shelter, and in gaps in the initial plantings of colonisers.

Exotic tree, shrub and weed removal

The removal of exotic trees began early in 1996. The old-man pines and many of the blackwoods were felled and some milled for timber. All those not extracted for timber plus all branches and slash was cut into relatively small species and left to rot on the ground, contributing valuable organic matter to the soil surface. Several stands of blackwoods were left standing on more exposed sites to provide necessary shelter for native regeneration and plantings.

The willows were felled at ground level during winter (when leaves has been shed and the trees were not actively growing) and the stems and branches stock piled on the site and burnt when the heaps had dried in the winter. The stumps were painted with chemical and the stockpiled heaps repeatedly burnt and sprayed with chemical until the kill was 100 percent.

The black locust trees were felled and sectioned to rot on the ground while the abundant regenerating seedlings were either hand pulled or sprayed. Regeneration after the removal of the adult trees has been considerable and it is likely that seedlings will need to be controlled for several years.

Pampas was variously controlled by repetitive spraying, burning or by being cut close to the ground by chainsaw. Seedling regeneration, which is expected to continue as long as there are areas of exposed soil present, is controlled by hand pulling or spraying. Blackberry and gorse, the former at its worst in the wet tributary valleys, was cleared initially by scrub bar and the regrowth later sprayed with chemical.

The control of invasive weed species such as willow, pampas and blackberry has been particularly successful, in no small part because of the meticulous way the project team went about the initial clearing and regular follow up sorties.

The effect of large-scale tree and weed removal was to open up a wide range of new micro-sites for planting, and the felling of the problem trees prior to planting removed any future worry as to how the trees could be felled without damaging the planted native seedlings.

On the negative side, the removal of the intact canopy from the valley bottom served to draw the frost zone down to ground level exposing existing tree ferns and new plantings to some frost damage.

Planting the colonisers

The first plantings occurred between May and September 1996. Sixteen thousand natives were planted in the first three of five planting zones into which the valley was divided. Initial planting efforts were focused on the areas most at risk of invasion by problem weeds, the grassy heads of the small tributary gullies, other parts of the margin of the valley, and the margins of the stream where streambank erosion was a concern. The principal aim was to reduce the potential future impact of exotic weeds by establishing an effective barrier to invasion, hence the focus on the valley and stream margins; and to set the scene for nature to take over in due course.

Species selection

The species planted were selected using a number of criteria:

- They had to be able to tolerate the micro-site conditions (which included factors such as frost, wind exposure, summer baking, wet and dry soils, periodic flooding, and competition from weeds or pasture).
- The selection needed to provide a wide range of plant heights and form, and a variety of fruiting and flowering times and type, in order to attract a wide diversity of seed dispersing birds and pollinating insects, and to create a wide range of micro-sites for new species to germinate.
- Because the aim has been to recreate natural bush habitat, species were selected that were historically natural to the area.
- Species assemblages were chosen that would look natural and be visually appealing.

A unique species composition was compiled and planted in each of 51 planting areas within three planting zones in Year One.

Planting regime

Most plants were planted at spacings of 1.5–2 metres apart. These close spacings were adhered to so as to achieve canopy closure as soon as possible following planting (3–4 years), and thereby reduce the need for weed control after 3–4 years.

A further 16,000 plants were planted in 1997, and 8000 in 1998. By the end of the planting season of 1998 the open portions of the entire valley had been planted.

Streamside planting

The Mangahanene can rise rapidly in response to heavy rain and streambank erosion can occur. The loose uncompacted banks and aggressive flood waters mean that only those species able to anchor themselves quickly and resist flood flows can be planted.

Carex secta (a native sedge) has proved to be the most appropriate species in this situation. Its foliage flattens against the stream bank in flood flows unlike other more rigid plants like flax and even toetoe which offer some resistance to flow and tend to be uprooted during floods. *Carex* is quite tolerant of immersion in water and sediment and will quickly reorient its foliage when flood waters recede. This species also provides excellent shading to small streams and habitat for riparian wildlife. On steep stream banks it can be planted at right angles to the bank surface to avoid planting-induced slips.

Photographs 47 and 48: A variety of practical techniques were tested to improve the ease of planting and its likelihood of success. **Photograph 47:** The steep river banks and rapidly fluctuating stream flow required careful species selection and improvisation. *Carex secta* was used almost exclusively on steep banks within the flood zone because of its capacity to withstand flooding. **Photograph 48:** Horizontally and vertically placed fresh ponga logs and imbedded horizontally placed blackwood logs were used to anchor a collapsing segment of stream bank. Fifty percent of the ponga logs regenerated and their fibrous root systems will serve well to repel the stream in the future.

Native plant growth rates

Native plants have an unfortunate reputation for being slow growing, but experiences at Warrenheip challenge that notion. On several planting sites a number of species including lacebark, ribbonwood, five finger, kohuhu, wineberry, lemonwood and akeake grew in excess of a metre a year for each of the first two and sometimes three years. Some lacebark grew in excess of 1.8 metres per year. The sites of most rapid growth were usually sheltered, sunny and moist with fertile soils and were free from weed competition.

Site selection also plays an important role in determining growth rates. Native trees and shrubs generally have a quite narrow optimum site preference range, and while species will often survive outside that range growth will be slow. A thorough knowledge of native plant site tolerances and preferences is required to match appropriate species to appropriate sites and achieve the best results.

Post-planting maintenance

The secret to achieving high survival and rapid growth rates at Warrenheip has been the repeated and thorough spray releasing programme undertaken after planting. All plantings will have been released on average three times in the first summer following planting and two to three times in the following year. Plants growing on more difficult sites will be released again in their third year, but after that should be able to be left to fend for themselves.

Releasing is done with Roundup™ (glyphosate sprays are the only safe herbicides to use around native plants and along waterways). A one metre sprayed weed-free circle is created around the base of each plant. In some areas grass growth has been so vigorous that the grass growing between the sprayed circles has collapsed on top of the planted natives and smothered them. To overcome this problem grass and some tall weeds are now periodically cut back using a weed-eater or scrub-bar, and all newly planted seedlings are systematically marked with bamboo stakes so that they can be located.

Effective rabbit and hare control, and to a lesser extent possum control, is essential before and after native seedlings are planted, especially when the planted area is adjacent to farmland. Rabbits, in particular, can cause extensive damage to young seedlings over a short period, and have done so around the margins at Warrenheip. Rabbits and possums have been effectively controlled using poisonous baits in strategically positioned bait stations; however, it is important to "pulse" the bait applications to avoid the development of bait shyness, and regular revisits are necessary as new animals quickly occupy the territories left vacant by dead pests.

Pukeko have also created a nuisance at the Warrenheip restoration site where a small number of birds have been known to repeatedly extract large numbers of flax seedlings from their planting holes. This problem has since been overcome by planting heavier grade flax plants which the pukeko seem less capable of extracting.

Secondary plantings

The planting of later successional species and climax trees has been possible at the restoration site since year one because of the existence of appropriate planting sites under the canopy of the mature kanuka stands. Planting of climax species, that typically have a low tolerance of frost, wind and prolonged exposure to sun, may not be possible for several years on open and exposed sites, until the canopy of the planted colonisers has established sufficiently to provide sheltered micro-sites suitable for planting.

Approximately 80 different native plant species have been planted in David and Juliette's 12 ha valley over the past three years. The large number of species planted illustrates the diversity of micro-habitats that can exist along a riparian margin, and the importance of matching the appropriate species to the appropriate site. In all, in excess of 100 separate planting sites were identified for the valley, each requiring its own unique selection of plants.

Future directions

Now that an initial complete cover of plants has been established much of the hard work and expensive aspects of the restoration programme have been completed.

The continued monitoring and control of weeds will need to continue on a reduced scale for several years, and replenishment planting will be necessary where plants have died to prevent invasive weed species occupying those sites.

As the plants grow rabbit and hare control will no longer be required, but the need for possum control will increase inevitably as the area of suitable food and habitat increases. Control programmes for stoats, feral cats, ferrets and rats will need to be put in place in years to come as native bird species move back into the valley. Wasps have become an increasing problem as the volume of native plants have increased, and future wasp control efforts are planned to reduce their presence.

The marking and construction of walking tracks has already begun, and in some parts of the valley plant growth rates have been so fast that the vegetation is already having to be cut back to clear access.

The planting of later successional tree species (such as rimu, totara, tanekaha, matai, hinau, mangaeo and nikau) can now occur in several sites in the valley that were previously open and exposed, thanks to the 2–4 metre high shrub canopy that has established. The pace of this supplementary planting is completely up to the discretion of the owners, who may choose to allow these species to enter by natural means.

Photograph 49: In three short years much of the valley has been transformed from an exotic jungle to the beginnings of an indigenous paradise. Note, however, the turbid colour of the stream. The complete restoration of David and Juliette's valley will require the active participation of the landowners upstream.

Tips for successful riparian native plantings

The scale of this habitat restoration project may be larger than would be contemplated by many landowners, but the keys to success remain the same:

- Fence the area with permanent materials before commencing planting.
- Remove grasses and weeds from the planting sites by spraying or mechanical means before commencing planting.
- Carry out extensive and thorough pest control before, during, and for several years following planting.
- Budget for post-planting maintenance to occur for at least three years, at least twice each year for all plants planted.
- Ensure the labour, resources and organisational skills are available for post-planting maintenance before you commit to the planting and before the plants are put in the ground.
- Whenever possible buy good quality, well-hardened, appropriately sourced plant stock that is the correct size and in the correct container for the species and the conditions into which they are to be planted.
- Choose and plant only those species that are appropriate to the region and the specific planting site and, except in the most mild climates, avoid the temptation to plant all stages of succession at once.
- Ensure post-planting maintenance is actually carried out and that it is done adequately and when it is required.
- For natural bush restoration plantings, plant at spacings of no greater than 2 metres apart (the optimum in most cases is 1.5 metres).
- Plant a healthy diversity of species, and match appropriate species to appropriate micro-sites.
- Where no natural recruitment is likely to occur, and so as to increase the likely lifespan and self-sustainability of the bush/forest, plan to interplant with post-colonising species once the colonisers are well established (perhaps five years down the track).

- Remember that restoration of bush or forest remnants back to the species composition of the past may no longer be an achievable or ecologically sensible aim, because of the influences of agriculture, pests and weeds. Relative self-sustainability and increased biodiversity are probably more realistic aims.

Case Study 11: Commercial forestry and riparian management: environmental management by self-regulation

Weyerhaeuser New Zealand Inc. owns and manages 79,000 ha of production forest in Nelson and Marlborough. It is a subsidiary of Weyerhaeuser Company, a large USA-based forest products company.

Environmental management by self regulation

Weyerhaeuser has taken a proactive approach to environmental management. It espouses the concept of self regulation as an effective means of meeting preset environmental standards (such as those defined in the Resource Management Act 1991) and has developed an Environmental Management System (EMS) for its own forestry operation to demonstrate how it can work. Weyerhaeuser and the Tasman District Council are together participating in a joint project (partly funded by the Ministry for the Environment) to investigate the role of an EMS and its effectiveness in meeting the requirements of the RMA. Weyerhaeuser is also one of the first forestry companies in the country to obtain ISO 14001 certification.

An EMS is a system for managing the environmental effects of an organisation. It provides a process by which the environmental effects of that operation can be identified, monitored and controlled and where necessary, corrective action taken to mitigate or eliminate those effects. An EMS identifies the legal requirements of the operation and provides a system that ensures all staff are aware of the legal obligations and understand the procedure to meet them. The system has a check back loop so that policy and practice are regularly reviewed and improvements made where necessary, and it provides a means for documenting and recording environmental performance and compliance.

Weyerhaeuser has developed a comprehensive EMS for stream and water quality management within their forests. The printed EMS guide includes the following information:

- a summary of the potential significant environmental effects of forestry activities that may impact on streams
- a summary of existing science and information on the physical, chemical and ecological function of streams and riparian margins and the potential implications of forest management on those functions
- a stream classification system and the criteria by which each stream can be classified
- a substantial set of management guidelines and standards for each major forestry activity and each class of stream.

Stream classification

Weyerhaeuser has classified all its streams into one of four categories. The categories have been determined on the basis of the ecological, recreational and aesthetic values inherent in the stream.

Class 1: Streams of special significance

Class 1 is subdivided into:

- wetlands – existing wetlands greater than 0.5 ha in area
- habitat corridors – existing indigenous vegetation corridors extending along streams and linking indigenous reserves
- trout spawning streams – streams identified by the Nelson Marlborough Fish and Game Council as trout spawning streams.

Class 2: Fish streams

Streams known, or likely, to contain fish.

Class 3: Streams with high potential stream power

Streams not containing fish but with potential to regularly contain flows large enough to cause streambank erosion or transport slash downstream.

Class 4: Small streams

Gullies and small headwater streams not represented by the other classes.

Management guidelines and performance standards have been set for each of the following forestry activities based on their potential impact on each of the stream classes:

- mechanical land clearance
- herbicide spraying
- fertilising
- burning
- forest establishment
- pruning and thinning
- roading and earthworks
- harvesting.

Understanding the problem

Impacts of forestry on water quality

Sediment

Increased sedimentation is the greatest risk posed to streams from forestry activities. Available evidence suggests that the main contributors to increased sediment loads are roading, stream crossings and earthworks associated with harvesting (skid sites and logging roads). One study found that the harvesting period contributed an estimated 70 percent of the total suspended sediment yield over a 32-year period (Hicks and Harmsworth, 1989, cited by Langer). Another study showed a 42 percent increase in sediment yield from cable logging and a 700 percent increase from skidder logging, compared to pre-disturbance levels (O'Loughlin, 1980, cited in the Weyerhaeuser document).

Sediment yields from undisturbed pine forests are generally less than from pasture and as low as from indigenous bush catchments (Dons, 1987, cited in the Weyerhaeuser document).

Fertiliser

The fertilisation of pine forests in New Zealand has not been shown to seriously increase the concentrations of nitrogen or phosphorus in stream water except where fertilisers are applied directly to forest stream channels.

Pesticides

The greatest potential for pesticide contamination of water due to forestry operations is from direct spraying into open waterways and onto vegetated riparian margins, and spillages of concentrated chemicals washing into streams.

Fuels

Contamination of stream water as a result of fuel spills is a significant threat when fuel is stored close to riparian areas.

Impacts of forestry on instream habitat

Increased sediment loadings offer the greatest threat to instream plant and animal life in commercial forests. High sediment levels can alter habitat and food availability, reduce visibility and therefore food sourcing capabilities, and clog the filter feeding apparatus and gills of instream animal life.

The removal of stream cover at harvest time can significantly alter the shade and temperature regime of stream water and have a consequent negative impact on fish and invertebrate life in the stream. The riparian vegetation that provides the shade is also a source of food and organic matter to the stream and stream life.

Culverts, fords and other water structures, and slash and debris generated at pruning, thinning and harvest can all provide barriers to the migration of several fish species.

Impacts of forestry on riparian habitat

Riparian vegetation is as important to instream and terrestrial ecological health in commercial forests as it is in pastureland. Riparian plants provide shade, food, carbon and streambank stabilisation to the stream channel and its inhabitants, and food, habitat, shelter and a dispersal corridor to terrestrial wildlife. The mature pine forest ecosystem may provide some of these services but when the trees are harvested the riparian margin vegetation will need to be present for these functions to be fulfilled.

Riparian wetlands serve a vital role in intercepting and filtering out contaminants generated by forestry activities. To perform this role properly they must be kept clear of slash and heavy loads of sediment.

Managing the problem

Weyerhaeuser management standards and guidelines

Weyerhaeuser has developed a comprehensive set of management guidelines and standards which clearly state how Weyerhaeuser's operations should be managed in order to protect the relative values of streams of each class. The standards are specific to Weyerhaeuser's operations and geographic circumstances and are not necessarily transferable to other sites.

The performance standards include:

- retention of a riparian zone where vegetation must remain undisturbed from machinery or chemical spray, and where no earthworks, tracking or ground disturbance can occur. The width of this protection zone varies with the class of stream
- exclusion of planting (of crop trees), spraying (fertiliser and chemical) and burning within specified distances of each stream class
- requiring that supervisors of spraying operations hold current Advanced Growsafe certification
- requiring that all reasonable steps a be taken to reduce the likelihood of spray drift over protected vegetation, and the use of low fish toxicity herbicides is preferred adjacent to streams
- not permitting Class 1 wetlands to be drained or burnt over
- constructing tracks with regular cut-offs
- avoiding hot burns, to prevent nutrients and organic matter being lost from the soil, and avoiding burning on land with high erosion potential.

The existence of these standards and the Environmental Management System is no guarantee that acceptable environmental standards will be adhered to but the system does provide a process by which poor practice will be detected and the necessary remedial actions taken to prevent future reoccurrence.

Sediment management

Sediment has been identified as the greatest potential threat from forestry operations to stream water quality and habitat. Skid sites, roading and stream crossings are generally the greatest sources of sediment, although land soil disturbance at harvest and post-harvest periods, especially on steep land prone to heavy rainfall events, can be a significant source if not carefully managed. It is inevitable after the removal of the tree canopy at harvesting that greater quantities of rain will reach the ground more rapidly than when the trees were present. Substantial sediment contamination of streams is less likely to occur where the speed of water flow down harvested slopes can be reduced and where the exposure of runoff to disturbed soil is minimised.

Photograph 50: Bridges and culverts reduce sediment contamination and streambed disturbance but should be constructed in such a way that allows aquatic fauna to pass up and downstream freely. Sediment traps on the approaches to bridges and culverts will reduce the amount of sediment reaching the stream.

In addition to the Weyerhaeuser standards outlined above, there are several practices that will greatly alleviate the risk of sediment contamination of streams in commercial forest areas (derived from Weyerhaeuser, the LIRO New Zealand Forest Code of Practice, and other forestry operations).

Roading

- Locate roads on benches, ridges, and away from waterways and unstable areas where appropriate.
- Form water tables and install sufficient culverts, flumes and cut-offs to control runoff as soon as possible.
- Use flumes to carry runoff past loose fill onto stable ground.
- Avoid discharging runoff directly into waterways or onto spill.
- Install sediment traps, especially each side of stream crossings or bridges.
- Regularly maintain all water control structures and sediment traps.
- Keep track gradient low.

Stream crossings

- Use bridges or culverts wherever possible to reduce the use of open ford crossings.
- Ensure culverts provide adequate passage for fish, ie, ensure there are no drop-offs on the downstream side.
- Protect the ends of culverts from erosion using rock, concrete or wood.
- Minimise disturbance to the stream bed and to stream banks.
- Revegetate all approaches, abutments and batters.
- Control runoff from roads and intercept sediment contained in the runoff with sediment traps.
- Avoid steep approaches and cross streams at right angles.
- Where open fords are unavoidable, select a natural crossing with easy approaches requiring minimal streambed alteration.

Harvesting and post-harvest land preparation

- Minimise soil disturbance and compaction as much as possible during harvesting and confine tracking, landings and skid sites to stable ground. Use low impact extraction techniques on land prone to erosion.
- Place the last line of slash parallel with the stream to provide a filter to surface runoff and help create planting separation from the riparian vegetation.
- Leave wetlands undisturbed.
- Maintain a healthy natural riparian margin as a buffer between the stream and forestry activities.

Photograph 51: Logs and debris can cause serious problems when carried downstream, especially in steep catchments and with high and intensive rainfall as is the case in the Coromandel Peninsula. Lengths of railway track have been driven into the streambed at 1–3 metre spacings and have been connected with steel cabling to intercept and hold any large debris floating downstream during floods. Diggers periodically clear the structure of snared debris.

Instream and riparian habitat

The quality of riparian vegetation is the key to the maintenance of healthy instream habitat and terrestrial stream margin habitat. In a commercial forest environment it is the period during harvest and the following seven or so years that the stream environment is at greatest risk from the adverse effects of forestry. For this reason, it is important that the riparian vegetation remains intact and fully functional throughout this period. In the absence of any forest trees it must provide adequate shade to the stream, provide streambank stability during periods of elevated runoff, and serve as a buffer to repel or intercept increases in sediment contained in surface runoff. If the riparian margin is an important wildlife corridor then it must also continue to provide food, shelter and safe passage throughout the period of harvest and site preparation.

The desirable width of the riparian margin and the type of vegetation required to perform these functions, will depend of the size and nature of the stream, the natural, recreational and aesthetic values to be maintained, and the likely extent of the impacts of forestry on the stream environment. A 10 metre margin of flax, sedges and woody native shrubs may be sufficient on some streams to maintain the stream values, whereas on other sites a 20 metre zone with a significant tree component may be necessary. Environmental systems designed to protect riparian values in commercial production forests should be sufficiently flexible to vary the prescription from site to site and sufficiently long sighted and sensitive to be able to detect when protection measures are not adequate and modify the prescription accordingly.

Photograph 52: The retention of a margin of native or exotic riparian vegetation wherever possible is recommended to provide shade to the stream and a buffer to forestry operations on the surrounding land. Weyerhaeuser forests, Nelson.

Many of the practices outlined here apply equally to smaller farm forestry lots. The scale may be smaller with farm plantations but the impacts of poor practice on streams and water quality can be equally devastating. In every situation, regardless of forest size, good management will only be practiced when all employees at all levels are well trained and well informed about acceptable procedures and have a genuine will to implement the correct procedures.

Case Study 12: Riparian management in peri-urban Auckland: lifestyle blocks and landcare initiatives

A significant proportion of rural land surrounding our larger cities, particularly Auckland, is now occupied by “lifestylers” who derive most of their income from work in the city. Block sizes range from less than one hectare through to 20 ha or more and are generally uneconomic as agricultural units.

Water quality and riparian management issues are as prevalent in mixed land use and predominantly small-block catchments, as they are where more conventionally sized holdings predominate. Management of effects and the installation of catchment restoration schemes can, in fact, be more difficult because of the large number of landowners to deal with.

Understanding the problem

Motivation and cooperation

Small-block holders are generally motivated in different ways to conventional farmers with regard to environmental issues. They are not generally reliant on their properties as a primary source of income so the withdrawal of land from production is not always a prime concern. However, lifestylers can occasionally be quite reluctant to offer land for conservation type reasons, such as for riparian restoration. Some see riparian retirement as removing a disproportionately large amount of their property from their own direct control. Others are happy to plant and retire riparian land if there is likely to be an improvement in the visual outlook of the retired area and an increase in the presence of wildlife. Many see these attributes as contributing directly to improved property values.

From an organisational point of view, there can be many landowners in a predominantly small-block catchment and the cooperation of all or most of them is necessary in order to make significant improvements to water quality and habitat. The concept of landcare groups fits well with multiple landowner catchments and is an effective way to induce cooperation and concerted community action on the ground.

Riparian issues

All of the water quality and habitat issues that afflict streams in rural land are present in peri-urban catchments as well. In some cases the intensity of agricultural impacts may be reduced because the principal aim is not to maximise production, but this can often be replaced by intensified human pressures that come with increased roading, housing and rubbish and effluent generation. The high sale value of peri-urban land can also be a disincentive to riparian retirement.

Water quality can be a particularly important aspect to be managed because of the greater likelihood of stream water being used for drinking-water or recreational pleasure further downstream. The water supplies to many of our cities are often sourced in the hills and from the streams located around the city margins so maintenance of a high standard of water quality is a significant issue for management, as is illustrated in the Hays Creek study.

The re-introduction of indigenous habitat to urban and peri-urban environments has become increasingly popular in New Zealand cities. Christchurch City has lead the way in this regard with its Waterways Enhancement Programme, where elements of the original indigenous flora are being re-introduced to riparian margins through the city. Waitakere City has recently embarked on a similar programme. Well planned and structured riparian retirements can be established to accommodate water quality improvement and riparian habitat enhancement, and often the latter will create greater community motivation than the former. However, it is important to note that conventional native tree and shrub plantings alone may not lead to any great water quality improvements. It is important, therefore, that the priorities for catchment management are determined first and then the restoration works tailored to meet those priorities.

Flooding, and the causes of flooding, can be an issue in some hilly peri-urban areas. Development of upper catchment areas for housing can result in a significant increase in the speed and intensity of stormwater and runoff. As the intensity of housing increases so the area of culverting, sealed roading and roofing increases. Correspondingly, the canopy of vegetation to intercept rainfall and slow down runoff can decrease as trees are cleared for development. The result downstream is that flood flows are higher and more regular than previously, as more water attempts to pass through the channel more quickly. This issue is dealt with in the first case study below.

Managing the problem

Cedge and Lorene Blundell, Kumeu River

The Kumeu River and tributaries drain a catchment of approximately 30 km^2 at the northern end of the Waitakere Ranges. It joins the Kaipara River and flows into the Kaipara Harbour at its southern end. The river has relatively high nutrient levels and, as a consequence, considerable instream weed growth. It is a soft bottomed and turbid river, although the number and variety of instream invertebrates is greater than would be expected in a stream of this condition. The upper catchment is quite steep and the lower river is prone to quite rapid and high flood flows which, locals state, seem to be occurring more regularly in recent years. Streambank erosion is a problem in some reaches of the stream.

Pockets of remnant indigenous native bush remain along the river but sizeable portions are occupied by willows which are threatening to clog the channel. Much of the rest of the channel banks are clothed by a mix of exotic weeds and shrubs and rank grass.

Cedge and Lorene Blundell own a 10-acre block (4 ha) that backs on to the Kumeu, a few kilometres south of Kumeu township. Their primary riparian interest is to restore native vegetation to the riparian margin and hopefully attract native birds to visit and use the stream as a dispersal corridor. They are concerned about the number of floods occurring and the height of the floods which can back up over substantial portions of their land. They are also keen to do something to reduce the streambank erosion and slumping that is occurring in places along their river margin.

Photograph 53: Part of the Blundell property and the Kumeu River flowing past their boundary. The river rises rapidly with rain and periodically floods over onto the Blundells' pasture.

The Auckland Regional Council promotes riparian retirement and revegetation, and provides technical advice and native plants grown by schools participating in the Trees for Survival Programme. Plants supplied by the programme were planted on the Blundells' riparian margin and stream banks this autumn by St Kentigern students.

The planting of natives along the banks of rivers such as the Kumeu that are prone to flooding has been a cause for concern for local authority (Rodney District Council) engineers. Their worry is that the woody shrubs and trees growing on the stream banks can be the cause of flooding, and they suggest that grasses and groundcovers would be more appropriate species to plant.

Stream channel clogging by invasive willows can cause some water backup and increase the peak of flooding; however, streambank vegetation that is not actually occupying the normal flow channel is physically unable to have a significant impeding or disruptive impact on flood flow because only a small proportion of the flood flow will ever come in contact with the bank vegetation. Clues to the cause of increased flood flows are more likely to be found where most of the water originates – in the headwaters. In the case of the Kumeu, parts of the upper river area have come under increasing pressure from housing along with its associated infrastructure – roading, curb and channelling and culverting, and this is likely to be a contributing factor to increased downstream flood flows.

There is little that the Blundells can do to reduce the high nutrient concentrations in the stream. Very little surface water enters the stream from their small flat property, and the volume of water passing them in the river channel is too great for bank vegetation to have any nutrient stripping capacity. The high nutrient levels are best managed in the smaller headwater tributaries and at the sources of the nutrient supply.

The streambank slumping on the Blundells' banks is a function of the steep sided, narrow nature of the river and a result of many decades of farming and development. A substantial reservoir of sediment has built up on the sides of the river since forest clearance which is prone to periodic slumping when the river waters rise. Mixed native plantings of shallow-rooting, flood-resistant grasses and sedges such as toetoe and *Carex* species, and more woody and deeper rooting native shrubs and small trees, will better anchor the banks, but some continued slumping is probably inevitable.

Hays Creek landcare initiative, Papakura

The Hays Creek dam is one of 10 reservoirs in the Auckland Region managed by Watercare Services, supplying potable water to municipal Auckland, and particularly Papakura City. The 640 ha Hays Creek catchment, which feeds water to the dam, is comprised mostly of farmland. 78 percent of the catchment is owned by 45 private landowners, many of whom are small block holders. The remaining 22 percent of the catchment is owned by Watercare Services. Land use in the catchment is diverse and includes sheep and beef farming, farm forestry, viticulture and native bush.

Because the lake is a supply of human drinking-water, the maintenance and improvement of water quality in the lake and the catchment is critical. The Auckland Regional Council, in cooperation with Watercare Services, has facilitated a community-based landcare initiative aimed at improving the surface water quality in the Hays Creek catchment by involving local landowners in land management decisions and enhancement works.

Photograph 54: Riparian retirement and native revegetation in the Hays Creek catchment, South Auckland.

Watercare Services has committed funding of $15,000 per year to be used to construct riparian and bush lot fencing, and purchase some plant material (eg, poplars) for land stabilisation. This money pays all of the costs of fencing materials and covers half of the cost of fence construction labour. Each landowner is required to contribute 50 percent of the fence construction either in cash or as labour. All of the native plant material is grown by local schools as part of the Trees for Survival national revegetation programme and the schools also carry out most of the planting under the guidance of the Auckland Regional Council. ARC provide staff to coordinate the programme and provide technical expertise. Work completed to date includes 10 ha of riparian margin and bush areas retired, several thousand native trees planted, and several thousand poplar poles planted.

Photograph 55: Gently sloping valley bottoms such as this one in the Hays Creek catchment are ideal for trapping sediment and phosphorus and slowing down the speed of water flow provided the valley bottom is fenced from stock and allowed to develop a thick growth of weeds and rushes. The near face has been recently planted with poplars to stabilise the soil erosion.

The landowners are responsible for the maintenance of their planted areas, including fence upkeep, spray releasing of natives, general weed control, pest control and silviculture on a few exotic timber stands established. Post-planting maintenance is critical to the success of the plantings and the programme overall, and to ensure the appropriate work is done on time a clear protocol of responsibilities has been developed. ARC staff monitor plant survival and maintenance work and provide feedback to landowners on these matters.

The width of the riparian margin retired is decided in negotiation with each landowner, and in most cases is sufficiently wide for a thick grass sward to establish and serve as a filter to surface runoff. Many of the small valley tributary streams are spring fed. Retirement from grazing encourages the re-establishment of native sedges, rushes and flax in and alongside the headwater channels. Supplemented by plantings of the same species, they function very effectively at slowing down the speed of water before it gains any downward momentum and filtering out the solids (sediment, nutrients and faeces) contained in the flow. The native trees and shrubs will not contribute greatly to controlling the flow of contaminants in surface runoff but they will help to anchor stream banks and encourage the return of native birds and other wildlife, as well as improving the visual appeal of the property.

The Hays Creek catchment landcare initiative continues to gain momentum as other landowners see work being done on neighbouring farms and appreciate its benefits. As in most catchment projects of this nature, there remain landowners who continue with land management practices that are clearly not sustainable from the environmental perspective or from a farm productivity perspective. Hopefully, sustained and subtle communication and education within the local community will see all landowners buying in to the project in due course.

Case Study 13: Commercial vegetable growing in the Franklin District: the search for sustainability

Brent Wilcox is a director of AS Wilcox and Sons Ltd, commercial growers of vegetables in the Franklin District, south of Auckland. AS Wilcox and Sons Ltd grow onions, carrots and potatoes for export to Europe and Asia. They produce their crops on over 800 ha of land in Franklin, Matamata and near Ohakune.

Brent and his company are active participants in the Franklin Sustainability Project, a multi-stakeholder project set up to address issues of sustainability in the commercial vegetable production industry. The project exists because of the realisation from within the industry and outside that there are aspects of commercial vegetable production that have a negative impact on the environment. Brent Wilcox and other growers are keen to find ways and practices that will enable them to reduce their impacts on soil and water values while maintaining their productivity at competitive levels.

Understanding the problem

Sediment loss/soil erosion

Sediment loss (soil erosion) and nitrate contamination of groundwater are the two biggest environmental issues associated with vegetable production.

Monitoring studies at two sites near Pukekohe have shown that large amounts of soil are, and have been for decades, moving from upper slopes to lower slopes. On average 2100 tonnes per square kilometre per year, or 98 mm of topsoil, have been moving downslope since 1952 (Environment Waikato, 1998). Less than 1 percent of this is being recovered from drains or roads; a significant amount of the rest is finding its way into streams and ultimately out into the sea or into the Manukau Harbour.

Soil loss in surface runoff is a major risk on land used for vegetable production for a variety of reasons:

- Large areas of bare earth are exposed to rain at any time.
- Regular cropping and cultivation has reduced soil organic content and structure, which increases the propensity of the soil to be transported by surface runoff.
- Soil compaction from repeated passes of cultivation equipment can create tillage pans which reduce water infiltration and promote increased runoff.
- Across-contour cultivation (ie, up and down the slope), necessary for the utilisation of sophisticated harvest and cultivation equipment, channels and concentrates runoff and encourages soil erosion.

Photograph 56: Deep scouring on a 10° slope near Bombay following the January 1999 storm. Note that the soil has been eroded down to a soil pan created by repeated tillage. *(Photograph supplied by Tony Thompson, ARC.)*

Photograph 57: Large-scale cultivation virtually to the edge of the Manukau Harbour and its tributary drains and streams can result in very high sediment loadings into the harbour during rain. Note the narrow area of bunding and no cultivation along the harbour edge. This will be preventing some sediment entering by this route. However surface runoff is clearly passing directly into the side stream where there is no bunding.

If soil loss is to be reduced, one or more of these aspects of exposure of soils to surface runoff needs to be removed or reduced.

Alternatively, measures can be taken to intercept surface runoff containing soil and prevent it entering waterways. This is very much a less favoured (albeit necessary) option because it does nothing to reduce the cause of soil (and probably nutrient) loss from where it is most valuable, on top of the hill. It is very much a last line of defence.

Nitrate leaching to groundwater

In recent years high levels of nitrate have been detected in groundwater supplies in the Pukekohe area. It has been suggested that commercial vegetable production may largely be responsible for this. Vegetable growers have certainly increased nitrogen fertiliser usage in recent years, as have dairy farmers, and this has been because of the positive growth response of crops to increased application. Some growers are applying well in excess of 200 kg of nitrogen per hectare per year, well in excess of what most crops can utilise.

Nitrate contamination of groundwater can occur excessively as a result of a variety of practices:

- excessive application of nitrogen fertiliser – in excess of what the crop can utilise
- application of fertiliser onto saturated soils, immediately prior to rain, or at times when plants are not growing at optimum rates
- application of the annual nitrogen dressing in one application, rather than split dressings
- excessive irrigation, over and above the water needs of the crop plants (promotes increased leaching).

Nitrate contamination can only be reduced by modifying management practices.

The reduction or avoidance of soil and nitrogen loss is likely to benefit crop productivity and profitability as much as it will benefit the environment.

Pesticide contamination

The extent of pesticide contamination of groundwater and surface waters arising from vegetable production is not well known. Herbicides are known to be transported in runoff when rain immediately follows application, and measurable concentrations of some pesticides have been detected in groundwater below areas of intensive horticulture.

Managing the problem

International market pressures

Brent Wilcox acknowledges the increasing international market pressure for the supply of environmentally friendly food products. European consumers, in particular, are demanding high standards of food safety and sustainability of production from their food suppliers, and Brent and others in his company are now looking at the sustainability of their own production methods and whether they can justify to themselves and to their international clients the current rates of chemical and fertiliser application and the impacts of other practices.

The Franklin Sustainability Project

The Franklin Sustainability Project is owned by the Pukekohe Vegetable Growers Association (PVGA) and is managed by PVGA's Environment Sub-committee and Agriculture New Zealand Ltd. The project is coordinated by a project team with representatives from PVGA, the NZ Vegetable and Potato Growers Federation, the Auckland Regional Council, Environment Waikato, Franklin District Council, MAF Policy, AGMARDT and the Ministry for the Environment.

A vision of "environmentally friendly and economically viable commercial vegetable growers" has been set by the PVGA, and two goals have been developed to achieve this vision:

- test and demonstrate sustainable land management systems relevant for commercial vegetable growing in the Franklin region
- establish a pathway for the uptake of appropriate sustainable land management information and technology by grower members.

Working towards meeting these goals the Franklin Sustainability Project has been formulated and funded for three years (to June 2000) to address key sustainability issues in commercial vegetable production:

- to evaluate the physical, biological and chemical qualities of soil and their effect on commercial vegetable production
- to demonstrate the use of surface water management techniques
- to illustrate methods of effective water usage
- to demonstrate the introduction and management of Integrated Pest Management Systems and biodiversity in commercial vegetable production systems
- to illustrate where possible what environmental or economic benefits could accrue from more sustainable vegetable production systems
- to achieve a long-term change in environmental awareness amongst commercial vegetable growers.

The project has developed some "best-guess" management practices for each of these objectives and has set about trialling them on three grower properties.

Soil erosion and surface water management

FSP is testing several methods of managing surface runoff to reduce soil loss, including raised accessways, benched headlands, silt fences and ponds, and contour drains.

Photograph 58: Silt traps on AS Wilcox & Sons' property near Mercer. Silt traps of this nature work well in trapping sediment and slowing down water flow, *provided* they are regularly maintained and emptied of accumulated soil.

AS Wilcox & Sons has installed a network of silt traps for trial at its Mercer property. While this practice does not reduce soil loss from the cropping area it is likely to reduce sediment levels reaching the stream below. Sediment traps such as these require regular maintenance (ie, removal of sediment) in order to function properly. Wilcox has also installed a large pond as a silt trap at the base of its property and planted the banks of a feeder stream with native flax, *Carex,* and native trees and shrubs.

Photograph 59: Sediment ponds such as this one at AS Wilcox & Sons can effectively trap much of the sediment lost from the productive areas. While sediment traps and ponds are effective management tools, they do not prevent the erosion of soil from productive land. Management practices which lead to the prevention of soil loss are most needed in the Pukekohe vegetable growing area.

While the planting has added some visual appeal to a rather barren landscape, it is probably doing very little to improve the quality of water flowing down to the pond. This is because very little of the stream water comes in contact with the vegetation and also because rather excessive use of Roundup™ (glyphosate) between the plants has removed all other vegetation and in so doing removed much of the filter capacity of the zone to surface runoff. Grasses and sedges serve as the most effective filters of sediment and should be retained in areas where surface runoff is likely.

The practice of benched headlands is another stopgap, last-line-of-defence measure that may capture some of the soil transported in runoff before it reaches the stream. This system may work even better if the bench or mound was planted in silt tolerant grasses and sedges. The plants would filter out and trap the sediment in the runoff and grow through it binding it to the soil with their roots. Grass and sedge filter strips could perform a useful function if grown alongside all drains, headlands, and roads, and would be invaluable as a means of slowing down surface runoff if grown as continuous belts across the middle of slopes.

The use of cover crops during high rainfall months and when ground lies fallow between crops is a proactive approach to the problem that should reduce the exposure of soil to runoff and retain the soil where it is most valuable. The growing of cover crops can also serve to boost soil organic content, important if soils are not to become merely inert growing media.

Nutrient management

FSP is currently investigating the capacity of cover crops to reduce nitrate leaching to groundwater.

Greatest nutrient loss occurs when more nutrient is applied than can be utilised by the plants or held in the soil. The practice of applying only what the crop needs, at times when it can best be utilised and avoiding times when it is most likely to be carried out of the system, is a cost-effective method of reducing nutrient loss from soil. This approach requires a knowledge of each crop's fertiliser requirements and an ability to do nutrient budgets based on the crop type, time of year, soil type and soil fertility, and prevailing conditions. Regular soil testing is essential.

Irrigation management

The same principles apply to the management of irrigation water as to nutrient management. Apply only what is needed when the plant most needs it. The ability to carry out water budgets and determine oncoming times of water deficit would be a useful skill for growers, and would reduce water wastage and consequent nutrient leaching.

Practical research requirements

More information is needed as to how and when soil and nutrient losses occur from commercial vegetable crops before more effective management practices can be developed. Prevention is a better option than an “ambulance at the bottom of the cliff”, but preventative practices will need to be developed that do not unduly impede growers’ ability to maintain and improve productivity, and this requires the full buy-in of all growers.

Case Study 14: Sustainable land and water management in the Waitomo Valley: reducing erosion to save a cave

The upper Waitomo Valley, north and west of Te Kuiti, comprises around 5000 ha of hill country, rising from 50 m to 450 m above sea level. Two major sub-valley systems combine to form the Waitomo Stream which flows to and through the renowned Waitomo Glow-worm Cave. Several other limestone caves exist in the valley.

The natural vegetation of the area was a podocarp-broadleaf temperate rainforest. European settlers deforested most of the hill country around 1900–1920, far later than most of New Zealand. Today the catchment is dominated by pastoral land where sheep and beef farming predominates but with increasing dairy heifer grazing. There are also sizeable areas of plantation forest, private native bush and conservation land.

Understanding the problem

History

The hill country of the Waitomo Valley descends to a small alluvial plain, the downstream end of which is closed off by a low saddle. Cutting beneath this is the Waitomo Glow-worm Cave. The cave was probably once a large natural tunnel, perhaps 20–30 metres high. At the stream level it is now, because of sediment deposition, a large chamber culminating in sumps and a low stream passage. Most of this change can be ascribed to sea level change since the last ice age. In the last hundred years, however, accelerated erosion in the catchment has caused a further 3–4 metre increase in the height of the floodplain upstream and downstream of the cave. The airspace in the submergence, through which tour boats exit the cave, is now only 3–4 metres high and can close completely during flood.

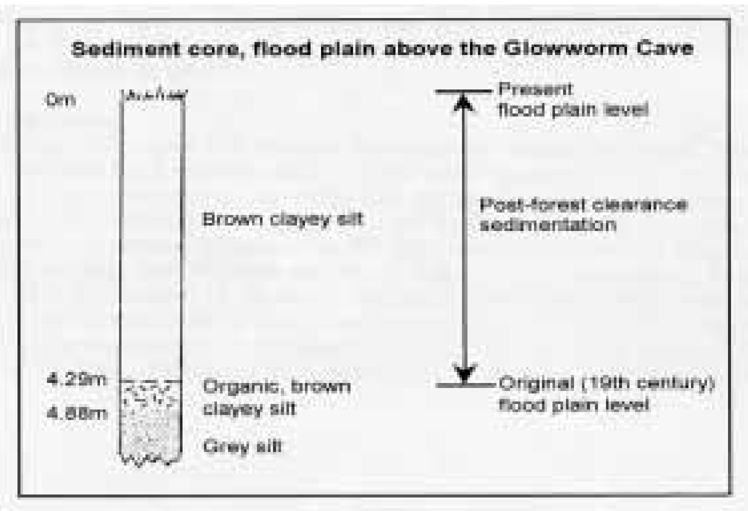


Figure 11: Sediment core taken from the glow-worm cave showing the depth of sediment deposit since forest clearance began in the catchment.

In 1974 a report suggested that the remaining life of the Glow-worm Grotto (a major tourist attraction in the caves) could be less than 50 years because of the sediment build-up. In response to this, a mutlidisciplinary Waitomo Caves Research Group was set up that year. Catchment management was a key need recognised by the Group:

- to attenuate flooding, which caused lost revenue and lost reputation, and needed cleaning up
- to preclude the need for expensive desilting by reducing the upstream erosion
- to improve stream ecosystem health which influences the health of the glow-worm population.

Riparian protection would provide organic material, lower stream temperature, reduce sediment load, and generally contribute to a healthy stream ecosystem.

The first catchment scheme for the valley commenced in 1980 with central government agreeing to pay two-thirds of its cost. However, only $64,000 was ever spent of the estimated $200,000 cost for the programme, partly because of local landowners' lack of interest in the tourist cave business, which they felt contributed little to the community.

The catchment scheme was rekindled in 1992 by the new cave owners, the Ruapuha Uekaha Hapu Trust, and by Environment Waikato who was keen to introduce the landcare concept to the Waitomo situation. Landcare was successfully developed in Australia in the 1980s as a grassroots approach to land management where local communities take the lead in sorting out local issues. A public meeting was called, which was well attended, and a selection of community representatives were elected to the Waitomo Catchment Trust. The Trust Board set about developing a strategy that would deal to the primary land and water management problems in the catchment.

Land and water management issues

The principal land and water management issues identified were:

- a trend to heavier grades of stock, away from sheep towards cattle, with some bulls and deer
- animal pests such as possums and goats, limiting the rehabilitation of forest remnants
- some soil creep and slip in limestone areas
- significant mass movements on the sandstone blocks during rain
- continued slumping on road batters
- some streambank erosion
- sheet erosion on intensively used land
- erosion from farm access track maintenance and blade disturbance for fencelines.

Current riparian issues

The predominant historical focus for land and water management in the catchment has been soil erosion causing elevated sediment levels in stream water. Evaluation of stream monitoring records since 1993 suggest that the Waitomo Stream does have a sediment problem especially during heavy rain events; however, there has been a significant (perhaps as much as 60 percent) reduction in the average sediment load in the Waitomo Stream when the period prior to 1993 is compared to that after 1995; this parallels the observation of some farmers in the catchment that stream water is not as dirty as it used to be (Rien van der Wetering, Environment Waikato, personal communication).

Monitoring records show that the Waitomo Stream also has a significant bacterial contamination problem, and that the level of contamination appears to be increasing. The likely reasons for these high and increasing bacterial levels are discussed in more detail in the property profiles below. The trend towards more cattle and the continued free access of cattle to the stream over parts of its length are quite probable contributors.

Nitrogen, and to a lesser extent, phosphorus levels in the Waitomo Stream are sufficiently high to promote nuisance plant growth. Phosphorus contamination is likely to occur in association with sediment contamination (as phosphorus binds readily to sediment particles), whereas the nitrogen is more likely to enter the stream system directly from livestock with access to the stream or from shallow groundwater seepage.

Waitomo Stream Condition Score: Contaminant Loading and Habitat Condition

Bacteria: HIGH to VERY HIGH
probably from cattle with direct access to streams and from sheet runoff

Nutrients: MODERATE to HIGH
nitrogen, and sometimes phosphorus, concentrations above levels that can cause nuisance weed growth

Sediment: HIGH but IMPROVING
bush and riparian retirement appears to be reducing sediment inputs considerably

Aquatic habitat: VARIABLE
reduced sediment and pockets of trees providing shade (and maintaining low water temperatures) create patches of good habitat

Riparian habitat: VARIABLE
areas of native bush remain in several parts of the valley

Score scale:

Bacteria: Enterococci: >6 = moderate; >33 = high; >150 = very high. Faecal coliforms: >40 = moderate; >200 = high: >1000 = very high.

Nutrients (g/m^3): Nitrate: >0.1 = moderate; >0.5 = high; >2 = very high. Total phosphorus: >0.01 = moderate; >0.04 = high; >0.1 = very high.

Sediment: turbidity (NTU): >2 = moderate; >5 = high; >10 = very high. Suspended solids (g/m^3): >4 = moderate; >10 = high; >20 = very high.

Aquatic and riparian habitat: visual and/or monitoring assessment.

Managing the problem

Strategy for implementation

Funding support was offered by Environment Waikato to the extent of providing 35 percent of the cost of the scheme over three years. The Waitomo Catchment Trust Board, representing the local community, had the task of raising the other 65 percent. This was about $200,000 originally but eventually came to around $340,000 with expansion. Annual or regular contributions have come from the owners of the cave, the operators of the cave, two of the main adventure cave operators, the Waitomo District Council, and the Department of Conservation.

Farmers who chose to participate in the scheme received full reimbursement for all riparian, soil erosion and native bush retirement fencing undertaken on their property. The responsibility for maintenance of the fencing, and some maintenance costs, fall on the farmer. Where commercial forests were planted the farmers contributed half of the Trust Board's contribution (that is, one-third of the full cost) on the understanding that all the costs associated with fence maintenance, silviculture and harvest were to be incurred by them in return for all of the proceeds from logging.

Property Protection Plans were compiled by Environment Waikato land management staff for each farm that participated in the scheme, and in those plans were recommendations for soil, water and riparian management and retirement. A condition tied to the provision of funding for the implementation of the plans is that a Land Improvement Agreement must be placed over the works, and these are binding on the farm title for a 99-year period.

Catchment works completed

The 1992 scheme intended to:

- fence 12 km around 330 ha of native bush on Class VII and VIII land
- commercially afforest 220 ha of Class VI and VII marginal farmland and scrub
- open pole plant 42 ha of potential slips
- intensive pole plant 18 ha of earthflows
- install two sediment dams.

The enthusiasm of landowners has resulted in considerably more work being done than was originally planned:

- 50 km of fencing
- 339 ha of commercial afforestation on former grazing land
- 264 ha of native forest purchased by the QEII National Trust
- 350 ha of native bush and scrubland permanently retired
- three dams and three reticulated water supplies.

Chris Kay

Chris Kay owns and manages 1000 ha of land in the Waitomo catchment, of which 520 ha are in grass. He has retired or sold (to QEII Trust) 220 ha of native bush, and has about the same in pine plantations plus a further 2 ha in Tasmanian blackwoods; 700 cattle (mostly bulls) and 1500 ewes are run on his pasture land.

Chris has been an active participant in the Waitomo Catchment Scheme since its revitalisation in 1992. Steep valley headlands have been fenced off and planted in pines, and all of his native bush areas have been retired from grazing. Difficult and erosion prone gullies, especially those linking to retired headlands, have also been fenced off.

Chris admits that he first became involved with the scheme because of his concerns for the plight of the Waitomo Caves if the same level of erosion and sediment contamination continued. However, as the fencing and tree planting have progressed and he has witnessed the benefits to farm management of the retirement works, he is now committed to the catchment programme by a genuine interest in sustainable land and water management. He realised as he retired the steep and difficult portions of his property that he had been spending 75 percent of his farm operating costs keeping the most difficult 25 percent of his land productive. The retirement of that 25 percent has freed working capital to be more profitably applied to the remaining 75 percent of his more productive land.

Photograph 60: Chris Kay has planted over 200 ha of his retired land in pines for later timber harvest. Chris will receive all of the proceeds from the timber harvested in return for retiring the land from grazing, paying one-third of the establishment costs and all of the fence maintenance and silviculture costs.

Chris's property is conspicuous by the length of unfenced stream running through it. He has been reluctant to permanently fence his stream margins because the stream is an important water supply for his stock and because the upper flats flood three or four times a year. If Chris installs two-wire electric fencing to exclude cattle from the stream channel the result is likely to be a significant reduction in the input of faecal bacteria and some reduction in nutrient input to the stream water, and there could also be a reduction in streambank erosion. Sheep may still gain access to the stream but their contribution to the bacterial and nitrogen contamination is likely to be small compared to that of cattle. Two-wire fencing is less likely to be damaged when the stream floods and less costly to repair if damage does occur.

Photograph 61: Chris Kay has constructed this retention dam at the base of a valley to trap sediment washed in surface runoff and reduce the velocity of runoff during heavy rain.

Mark Frederikson

Mark Frederikson is a next-door neighbour to Chris Kay. He owns 274 ha of land ranging from river flats to steep and more erosion-prone hills. Of this, 118 ha are clothed in native bush, some of which is fenced off, 52 ha are in pine forestry and 104 ha remain in pasture. He runs 240 cattle, 75 breeding cows and 600 ewes, and utilises another 75-ha leased block for grazing. Mark and his father began planting pines in 1974, and as the trees reach maturity a significant part of his cash flow will be derived from timber.

A 1.8-ha block of native bush has been protected and a QEII covenant placed on it. Mark is keen to use the Waitomo Catchment Scheme to fence off the majority of his native bush areas. Like Chris Kay, he has not fenced off his stream margins but can see the advantages in doing do.

Photograph 62: Forty percent of Mark Frederikson's farm is covered in native bush. 1.8 ha has been placed under QE II covenant and Mark is working towards fencing most of the rest of the bush areas from stock.

He has noticed a distinct improvement in the clarity of the stream in recent years (as has Chris Kay) accompanied by a definite reduction in silt on the stream bottom. Interestingly, he also feels that there has been an increase in the amount of oxygen weed growing in the channel which may be because of an increase in stream nutrient concentrations.

Changing motivations and attitudes

By Chris Kay's admission, it is doubtful whether the Waitomo Catchment Scheme Trust would have had anything like the success that it has if funding for 100 percent of the project works had not been made available. In the 1980s, even the availability of funding was not sufficient to motivate interest. Having experienced the benefits of appropriate land retirement and diversification of land use (with the planting of stands of pines) Chris, in particular, acknowledges that farm productivity and profitability have not fallen as a result of the project works. He is hungry to complete works on the remaining 25 percent of his property.

Case Study 15: Mangakahia River Valley Landcare: managing water and weeds in Northland

The Mangakahia River drains a catchment west of Whangarei and adjoins the Wairoa River which eventually flows past Dargaville and into the northern end of the Kaipara Harbour.

The Mangakahia catchment is 800 km^2, which is large by Northland standards. In 1990, 55 percent of the catchment was in pastoral farming, 20 percent in plantation forestry and 25 percent in podocarp forest and scrubland. Local and regional council opinion is that there has been an increase in plantation forestry over the past nine years at the expense of pastoral land, and also a trend towards dairying or bull farming in place of sheep.

Understanding the problem

The Mangakahia River Landcare Group

A group of Mangakahia Valley landowners have formed a valley care group to confront some of the more significant environmental and farm production issues in the valley. Their emphasis is very much on weed control, erosion control, water quality, flooding and pest control. The Northland Regional Council and the New Zealand Landcare Trust provide technical input, attend the meetings, and assist with promotion of the group's various initiatives.

The landcare group is driven largely by a small group of enthusiasts, and one of their key concerns is how to get action out of other landowners in the valley. There is a level of despondency about the size of the environmental problems facing them and general apathy of many to these problems.

One of their more recent projects is to rid the valley of tobacco weed (woolly nightshade). The group consider it is one weed that is not so widespread in the valley that it can't be controlled. A mix of mail-outs and phone surveys have determined the extent of the problem and drummed up voluntary assistance for group weed-clearance days.

Mangakahia Valley riparian issues

Water quality

The Mangakahia River is a typical agricultural river. It floods regularly and rapidly (eight "one-in-50 year" floods in 18 months) carrying large volumes of silt with it. Even at normal flow it is turbid. The river channel is narrow and banks are clothed with pasture to the water's edge. The river banks are devoid of any trees or indigenous vegetation in many parts and are prone to quite severe slumping and erosion. Farm stock still have free access to the river's edge along much of its length, often because many farms do not have reticulated water systems for their stock.

Photograph 63: The Mangakahia River, Northland. An entrenched, steep banked and erosion prone river channel that is largely devoid of riparian vegetation and prone to frequent flooding.

The hills surrounding the river through which tributary streams flow become saturated in the winter and are prone to large scale slumping and mass movement.

The substantial increase in dairying has lead to an increased use of nitrogenous fertilisers with an associated increase in nitrate leaching, and probably bacterial contamination of streams via overland surface flow.

While there is no water quality data available for the river, it is reasonably certain that sediment levels will be very high, and that nutrient and bacterial levels will be higher than is desirable.

Impact of increased pine forestry

There have been substantial increases in pine plantations in the Northland region, including the Mangakahia Valley, in recent years. Approximately 8000 ha a year are being planted in exotic plantations (mostly pines), half of which is corporate forestry and half farm forestry. It is estimated that 12.5 percent of Northland is now established in exotic forestry.

The increase in forestry in the headwaters is likely to have a significant and positive impact on soil erosion and flooding once the trees grow and establish a canopy. Water from heavy rain events is released considerably more slowly by a forest canopy than by grazed pasture with the result that flood flows rise more slowly and do not reach the same high levels. Soils under pine forest do not become saturated as rapidly nor for as long as open pasture soils and so are generally less prone to erosion.

Much of the new forestry is being established on the steeper, less productive land. This will remove that land from previously unproductive pastoral farming; however, there may be future erosion and water quality issues when harvesting begins.

Managing the problem

John and Christine Pederson

John and Christine Pederson farm 232 ha on the flanks of the Mangakahia Valley. They run 500 ewes, 400 replacements, 60 cows, 100 yearling bulls and 30 heifers. Forty hectares of their property are planted in forest trees.

They both describe themselves as tree buffs and have set about planting a wide variety of species for a range of purposes in the 34 years they have been on the property.

The Pederson property does not lie directly alongside the Mangakahia River, but they do have five streams which feed the river. All five streams are fed by small springs and some runoff, and all tend to dry in the summer.

Soil erosion

Soil erosion is perhaps their most serious land management problem. The soils are such that some areas of their property are effectively large earthflows. Movement occurs in the winter when soils become saturated. To anchor the worst of the earthflows John has mass planted poplars over large areas. The poplars have effectively stopped the earth movement and dried the soil to the extent that sheep can be grazed under the trees through much of the year. Tree spacings are quite close and the closed canopy will substantially reduce summer grass growth.

Eucalypts and pines have been planted at wide spacings, 200 and 400 stems per hectare (tree spacings between 7 metres and 5 metres apart), on steeper faces where there is some slumping. The wider than normal spacings have been designed to stabilise the slopes but retain sufficient light for grass to grow under the canopy. Eucalypts are well suited to this regime because their foliage provides less shade and they have less substantial lateral branching. *Eucalyptus muelleriana* is one eucalypt variety that appears to perform well in this part of Northland.

Possum damage

Possum damage to seedling and adult trees is a substantial problem for the Pedersons. John has found that the poplar hybrid “kawa” has been by far the most resistant poplar to possum damage of the many varieties tried. The Chinese poplar (*Populus yunnanensis*), not used on this property, is another that is possum resistant and has the added virtues of retaining its leaves well into winter and having a wide canopy that provides excellent shade in summer.

Water quality

The Pederson property is an attractive mosaic of trees and pasture. Steep and erosion-prone faces are planted in eucalypts and pines, wet earthflow areas have a covering of poplars, remnant native bush stands remain in some gullies and mixed native and exotic plantings follow all of the stream channels down from their feeder springs. Constructed ponds in the valley bottoms add to the aesthetic appeal of the property. Shade and shelter are well situated for livestock, and erosion has been well controlled by tree planting.

The control of erosion has no doubt reduced sediment loads in the streams but some of the stream channels, and the headwaters of one stream in one area of native bush, remain open to livestock. These are potential sites for faecal bacteria and nutrients from dung and urine to enter the stream system, more so because cattle use the stream for shade and shelter during the summer. The native area, valuable as summer shade and winter shelter, has been well grazed so that there is little or no native understorey and some stem and root damage to adult trees. It would benefit from retirement.

The rank grass that exists under the retired pine and eucalypt stands will function well to reduce the speed of surface runoff and trap any sediment contained in it. In those stands where grazing continues, the removal of stock, or a reduction in grazing, in late autumn and throughout winter will enable a longer grass sward to develop and trap sediment contained in winter runoff.

Andrew and Anne Fraser

Andrew and Anne Fraser run a 400-cow milking herd on 183 ha beside the Mangakahia River.

The farm occupies the peninsula on the inside of a sweeping meander in the river. The soil in the central elevated part of the farm is clay and the outer portion alongside the river comprises an alluvial, silt loam that is rather slow to drain. Maps from the turn of the century reveal that the river flats were once riparian wetland sustaining a thick riparian kahikatea forest. The central clay portion was once occupied by kauri.

Unfortunately for the Frasers, part of their farm occupies the alternative flood channel for the river. In very high flows the river rises over its banks and takes a short cut across farmland to link back with the main channel again. The early maps show that this flood channel has long been in existence. The channel is a natural depression and a small lake (which still exists) and riparian bush once occupied the strip. Today it is prime dairy pasture – that is, when it is not under water. In normal years, the Frasers would expect to have it flooded once or twice, but over the past 18 months or so (in 1999 and 2000) it has been flooded on eight separate occasions.

River bank erosion, flooding and poor terrace drainage would be the primary water management issues confronting the Frasers.

The river channel

The river channel is entrenched and narrow. The banks are largely grass covered and prone to slumping and erosion, especially on outside bends. It is, in this regard, a typical pasture river.

Photograph 64:
Riverbank and slump erosion are significant management problems for the Frasers.

The actions of vegetation removal, cultivation, livestock and surface runoff carrying sediment, both on the farm and from upstream, have lead to an accumulation of sediment in the channel causing it to narrow. Research suggests that if it was possible to eliminate all or most of the sediment input from upstream then the river would gradually widen its channel by carving out the accumulated sediment from the river banks and carrying it downstream and out to sea. In catchments where forestry is being established in the upper catchment and riparian retirement is occurring on the farmland the volume of sediment entering the river system is becoming considerably reduced. This in itself is a good thing but the side effect is that in a low sediment input regime the river will attempt to revert to its old wider channel shape and will erode away increasing amounts of silt from the banks. This is likely to become an increasingly common occurrence on farmland where efforts to improve water quality are taking effect.

The river bank erosion is likely to be more pronounced alongside the Fraser property because of the lack of any tree or shrub cover to anchor the bank sediment. Weeping willows used to occupy the channel but they mysteriously died. Now it is extremely difficult to establish any vegetation because of the regularity and extent of flooding. Even fast-growing poplars and willows struggle to anchor the loose sediment in time to withstand the next flood. Sediment anchoring trees are most required on outside bends where erosion is greatest, but of course, this is where the plants have the greatest problem remaining anchored.

Perseverance and the use of fast-growing, deep-rooting willows and poplars planted no further apart than 6 metres is probably the only option. At 6 metres or closer, the roots of the stand of trees will meet and form a complete flow-resistant mesh under the soil surface.

Close plantings of the native sedge *Carex secta* work well as bank stabilisers on the banks of less entrenched but equally volatile streams, but the Mangakahia banks are too high and contain too much unstable silt for the sedges to make a difference on their own. The laying and anchoring of tree fern trunks horizontally along the stream bank has worked well as a buffer on smaller streams (see *Case Study 10*) and may be worth trying on the Mangakahia. The trunks will sprout several shoots and sets of roots if there is adequate moisture present. Once established tree ferns provide excellent bank stabilisation qualities. Their substantial mesh of near surface roots strongly repel the forces of water especially when many tree ferns are growing closely together.

Flooding

Flooding is very much the product of the volume and speed of water being fed to the river by its tributary streams. There is nothing Andrew and Anne can do to lessen the height of flood waters, and so they must either choose to live with the effects or, if the repeated cost of pasture replacement becomes too great, choose to re-establish a riparian channel along the flood route and attempt to manage the flood waters within that channel.

The increasing area of maturing pine forest in the upper catchment may in itself reduce flood peaks in future, especially as the plantations begin to form a solid canopy and intercept rainfall.

Terrace drainage

Andrew has fenced off a remnant block of native bush and a wetland area on his property. On the rest of his flats he has installed a network of novaflow drainage piping in an attempt to reduce the tendency for pugging and pasture damage in the winter. The new drainage appears to be working well but the drains have their outlets at the river bank, by-passing the wetland areas and feeding nutrient and sediment rich water directly to the river. If the drainage pipes could feed to the wetland or at least to a surface drain before entering the river there would be some opportunity for the wetland vegetation to filter and absorb the nutrients and sediment before the water enters the river.

Photograph 65: Andrew Fraser has fenced off an area of remnant swamp forest on his property, a small reminder of what was the dominant vegetation type on the Mangakahia River terraces.

Photograph 66: Large, flat, grassy wetlands such as this are excellent processors of nutrient and sediment. Much of the nitrate entering this wetland will be converted to atmospheric nitrogen by the process of denitrification, and the thick vegetation will slow down the speed of flowing water allowing sediment particles to settle out. Andrew Fraser has installed subsurface drainage on his river flats to increase pasture utilisation during the winter. The drains feed directly to the river carrying nutrients, sediment and faecal bacteria with them. If the subsurface drains could instead feed into the wetlands, few of these contaminants would then reach the river.

Case Study 16: The Upper Kaituna Catchment Control Scheme: has riparian retirement been successful?

The Upper Kaituna Catchment Control Scheme was developed in the late 1970s to arrest the deteriorating water quality of Lakes Rotorua and Rotoiti, and to do it in part by controlling and preventing soil erosion, sedimentation and nutrient runoff from the surrounding catchment. The other part of the scheme was to reduce the sewage load from Rotorua City entering the lake.

Understanding the problem

Over the 50 years leading up to 1990 there was an increase in sewage volumes discharged to Lake Rotorua and an increase in catchment area developed to pastoral agriculture. Both the sewage and the catchment made significant contributions to the nitrogen and phosphorus budgets of the lake. The increased supply of nutrients affected the lake in several ways:[5]

- increased growth of algae decreased the clarity of the water
- surface scums of unsightly and potentially toxic blue-green algae occurred
- bottom waters had an increased tendency to become depleted of oxygen.

Some of these features were also observed in Lake Rotoiti, which receives outflow water from Lake Rotorua.

This continued deterioration in the water quality of both lakes was of concern to the local community, especially given the regional and national importance of the lakes to tourism, fisheries and conservation values. Out of this concern the Upper Kaituna Catchment Control Scheme arose.

Managing the problem

The soil conservation component of the scheme was implemented through the 1980s, and included tree plantings on the erosion-prone hillsides, preservation of wetlands and lake margins, and retirement and planting of stream riparian zones. These works were undertaken in the belief that they would reduce upslope entrainment of sediment and nutrients into surface runoff and bring about the entrapment of runoff contaminants within the retired riparian zone. Riparian plantings were also expected to reduce sediment and nutrient inputs to the lakes by stabilising stream banks against erosion and preventing stock access to the stream. While these expectations appeared to be reasonable at the time that the scheme was developed there was no hard scientific evidence available to support the expected outcomes.

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[5] Cooper AB, Williamson RB and Smith CM. 1990. *Assessment of soil conservation work in the Ngongataha catchment and the implication to Lake Rotorua*. Water Quality Centre DSIR, Consultancy Report No. 7061.

Consequently, as the soil conservation works drew to a close towards the end of the 1980s, the decision was made to investigate the degree of success of the scheme. The information in following sections outlines the findings.

The catchment of the Ngongataha Stream was chosen to carry out the investigation. In the early 1970s, before the soil conservation works began, the 7330 ha catchment consisted of 46 percent native bush, 6 percent exotic forestry, and 48 percent pasture. By 1990, 407 ha or 5 percent of the catchment had been retired. The retired areas included stretches along the banks of the Ngongataha (along 17.6 km or 90 percent of its total stream length), Umurua and Otamaroa streams, ephemeral waterways, headwater streams and swamps, and erosion sensitive hill slopes planted in conservation forestry or previously in native bush but accessible to stock. Eighty-seven percent of the works undertaken between 1980 and 1992 were subsidised by grants.

The strips of retired stream bank vary in width from 2 m to 100 m, although they are usually less than 40 m wide.

Species planted

Retired areas have been planted at a rate of 1200 stems per hectare. Native trees are now preferred as they are generally maintenance free and easily established; however, when the scheme began natives were not available in the quantities required and consequently a greater proportion of exotic species were planted than preferred.

Erosion prone hill slopes and gullies were predominantly planted with production forestry species *Pinus radiata* and Tasmanian blackwoods. Blackwoods were preferred because of their higher timber value and their slower growth rate, which would mean the retired areas would be disturbed less often. Douglas fir were also planted in production woodlots for the same reasons.

Subsequent experience is showing that blackwoods require considerable silviculture (form pruning) from an early age to produce a harvestable log; poorly formed trees can make up a considerable proportion of the stand especially in narrow riparian strips where a large proportion are exposed to exposed stand margins. Landowners have the responsibility of carrying out silviculture and maintenance works in the retired zones, but many of the blackwood stands have not received the required pruning necessary to produce a high value log.

Eucalypts (*Eucalyptus regnans*, *E. delegatensis* and *E. cordata*) were often planted in the initial stages of the scheme as they were readily available. Their propensity to be windblown has reduced their use in more recent times. Other exotics such as oak and walnut were also planted in the initial stages.

The stream banks and low-lying areas have been predominantly planted in native species, although a few shrubby willows have been planted along the Ngongataha Stream edge to reduce streambank erosion, and to serve as fillers in swampy tributary headwaters. Flax has been most used because of its hardiness and low cost. Other native species include karamu, kohuhu, lemonwood, akeake, kanuka, manuka, wineberry, cabbage tree, koromiko, kahikatea, ribbonwood, and rimu.

Monitoring the changes

The Ngongataha Stream was chosen for the study because the water quality and quantity databases from prior to the commencement of the soil conservation were more comprehensive than from other Lake Rotorua sub-catchments. The major part of the study, carried out in 1990, was to compare water quality before and after soil conservation measures were implemented. The study was carried out by the Water Quality Centre of the DSIR (now NIWA) and its main findings are summarised below.[6]

Sediment and nutrient loads

The prime aim of the study was to quantify the impacts that the catchment management scheme has had on loads of sediment, phosphorus and nitrogen to Lake Rotorua.

Sediment

Sediment exports from the Ngongataha catchment fell by 85 percent from pre-catchment works to the period following the works. This substantial reduction was thought to be due to a reduction in streambank erosion and a reduction in sediment contained in surface runoff.

Phosphorus

Total phosphorus yields were 24 percent lower when the soil conservation measures were in place compared to pre-catchment works. Retirement was associated with both reduced particulate and dissolved phosphorus exports, and this was reflected in substantially reduced exports in stormflow (34 percent) and slightly reduced in baseflow (4 percent).

Interestingly, in both pre-and post-retirement periods most of the dissolved phosphorus was transported during baseflow, and most of the particulate phosphorus was exported during flood flows.

Phosphorus concentrations (as opposed to load) generally fell following retirement.

Nitrogen

Total nitrogen exports were very similar under retired and non-retired conditions. However, there was an important difference in the partitioning of the nitrogen. Nitrogen was primarily exported as organic (particulate) nitrogen (70 percent) when the stream bank was not retired, whereas nitrate was the predominant form (54 percent) after retirement. Nitrate exports in stormflow did not differ between retired and non-retired conditions, but baseflow exports did. Estimated annual exports were 39–56 percent higher after the conservation measures had been implemented. The change from predominantly organic to nitrate export may be of real

[6] Cooper AB, Williamson RB and Smith CM. 1990. *Assessment of soil conservation work in the Ngongataha catchment and the implication to Lake Rotorua*. Water Quality Centre DSIR, Consultancy Report No. 7061.

significance, as nitrate is mainly exported during baseflow and as such is a continuous source of immediately plant-available nitrogen to Lake Rotorua.

In addition to the nitrate load increases, nitrate concentrations also increased between the mid-seventies and late eighties. There are two possible reasons for these increases.

These increasing nitrate concentrations and loads may be unrelated to the soil conservation measures and could instead reflect increasing groundwater nitrate levels in the Rotorua region because of the large scale changes in land use over the last 50 or more years. Much of the flow in Rotorua streams (and other areas with pumice substrates) is derived from springs and rapid subsurface runoff, and the proportion of surface runoff contribution to stream flow is small compared to streams on other substrates. It is for this reason that any increase in nitrate concentrations in groundwater will have a significant impact on stream water concentrations.

Average groundwater residence times can reach 50–100 years, which would coincide with the major period of conversion from native vegetation to pastoral land use. Because of the time delay, the effects of this historical land use conversion would only now become apparent as the groundwater emerges at springs to feed the stream. Average nitrate concentrations in the Ngongataha increased from 300 mg/m^3 in 1968–1970 to 531 mg/m^3 in 1975–1978 and 610 mg/m^3 in 1987–1989. This would support the argument that the nitrate increases have little to do with the conservation works. But it does raise the question as to whether we are yet to see the worst of nitrate levels nationwide, especially if we are having to wait 50 years or more before the original contaminated groundwaters re-emerge.

The other possible explanation for the nitrate increase could be that there is a decrease in the capacity of the riparian zone and/or the stream channel to remove nitrate following retirement. The denitrifying capacity of the riparian zone and the stream channel may have been reduced by the heavy plant cover established as part of the retirement process. Shade created by overhanging tree and shrub vegetation may have shaded out the macrophyte and periphyton populations in the channel thereby reducing denitrifying activity, and/or the new riparian vegetation may have drained the previously wet riparian soils also reducing the amount of denitrification able to occur.

There is no evidence from the Ngongataha to say which of the two theories is the most plausible explanation. However, information gained from the Whangamata Stream near Taupo (see *Case Study 4*) showed clearly that streambank shading dramatically reduced the capacity of the stream to strip the water of nutrients, because of the exclusion of semi-aquatic streambank vegetation. That stream is also predominantly spring-fed. Unlike the Ngongataha Stream, its spring water has shown no sign, in the period 1991–1998, of increasing or decreasing concentrations of nitrate (or phosphorus), which could be because that part of the Taupo region was not developed for intensive agriculture until the late 1950s. However, the nitrate concentrations in the Whangamata appear to be nearly twice as high as those in the Ngongataha. Clearly, there is more we need to discover before adequate predictions of cause and effect can be made.

Streambank erosion

Active streambank erosion was found to be occurring on 3.7 percent of a 14.3 km reach of the Ngongataha Stream in a post-retirement survey, compared to 30 percent pre-retirement. In addition, the average size of each erosion site was substantially reduced in the later survey.

The most likely reason for this change is because of the removal of stock and the planting of vegetation that has re-stabilised the banks. An alternative view is that the stream channel has reached a state of equilibrium following the removal of the original stream bank vegetation and its conversion to pastureland, and as a consequence bank erosion is no longer as substantial as it once was.

Photograph 67: Most of the Ngongataha Stream margins have been retired as part of the Upper Kaituna Catchment Control Scheme. Much of the stream's margins looked like this small unfenced portion prior to the commencement of the scheme. Note the straight stream channel and the unstable steep banks. Compare this to Photograph 64, a reach of the same stream not more than 100 metres away that has been fenced for many years.

Vegetation changes

A survey of vegetation within 5 metres of the stream channel undertaken in 1989 revealed that blackberry made up over 30 percent of the plant material growing there. This compares to an area that was predominantly grazed grass pre-retirement. Eighteen percent of the vegetation remained in exotic pasture grasses and 12 percent consisted of conservation plantings (these were under represented in the survey because vegetation was only measured within 5 metres of the stream). The rest of the plant material consisted of willows and other exotic shrubs. Semi-aquatic monkey musk (a species capable of stripping nutrients from stream water – see *Case Study 4*) made up 5 percent of the vegetation.

There was also a significant amount of vegetation overhanging the stream which was obviously not present when the banks were in pasture. This overhang provides important shade to the stream and may also supply terrestrial invertebrates (food) for fish.

Estimation of riparian margin nutrient and sediment stripping capacity

An evaluation of the effectiveness of the retired riparian margins in stripping nutrients from overland flow was carried out on the main channel of the Ngongataha Stream.

The field survey involved mapping the surface runoff source areas, identifying likely surface runoff paths (where channelisation obviously occurred), and classifying the intervening retired strip on its ability to remove nutrients.

Effective buffer strips were judged to be:

- where the stream is bounded by low gradient land which generates little surface runoff
- on steeper banks, where there is a wide buffer strip with a good thick sward of grass ground cover.

Poor nutrient stripping was judged to occur in the following situations:

- where the vegetation canopy had shaded out ground cover on steeper slopes
- where retired vegetation (grasses) becomes submerged by surface runoff in heavy rain
- where surface runoff enters an incised permanently flowing channel without previously passing through a buffer strip
- where the grassy buffer strip is too narrow to cope with the volume of runoff it receives.

The assessment judged that retired strips along about 55 percent of the main Ngongataha Stream removed most of the sediment-bound pollutants in surface runoff, but that strips along other reaches often had insufficient close ground cover to be effective. Blackberry and other weeds have proliferated within the retired strips, and the former appears to be preventing the establishment of a close ground cover, and therefore reducing the nutrient and sediment interception capacity of the strip.

What difference have the retired and planted Ngongataha Stream riparian margins made 10 years after retirement?

What has happened?

- Sediment loads have decreased substantially.
- Phosphorus loads and concentrations have decreased.
- Nitrate loads and concentrations have increased.
- Particulate nitrogen loads have fallen.
- Streambank erosion has decreased considerably.
- Weeds, especially blackberry, have invaded some riparian areas.

Why have these changes happened?

- Sediment and phosphorus reductions have probably occurred because of the effective filtering of surface runoff passing through the grasses in the retired riparian margin.
- Sediment levels would also seem to have been reduced by effective stabilisation of stream banks by planted vegetation, reducing bank erosion.
- Particulate nitrogen levels appear to have been reduced because of the filtering actions of the riparian margin.
- Nitrate levels have risen because of increased nitrate levels in emerging groundwater, and also because most nitrate does not pass through the riparian zone in surface water to any great extent.

Future recommendations and expectations

- In pumice substrate streams where a high proportion of water supply comes from groundwater, management of the spring heads and associated riparian wetlands may be the best (and possibly the only) way to extract nitrate before it enters the water body and becomes unmanageable.
- Substantial effort should be focused on reducing the production and leaching of nitrate at the source – on the farmland.
- What will happen to the nutrient and sediment trapping potential of the riparian margins when woody shrubs and trees begin to dominate? We may be faced with managing artificial grass strips in addition to riparian habitat to serve two separate functions.

Attitudes and opinions

Farmers in the Ngongataha were questioned as to their observations of changes resulting from the retirement works and their opinions of the value of the works. The findings were as follows:

- Most thought the retirement scheme had reduced soil erosion and nutrient runoff.
- Most thought the exclusion of stock, especially cattle, had been the most positive effect; followed by the stabilisation of stream banks by planted vegetation.

- Weeds, especially blackberry, were considered to be the biggest practical problem in retired areas. Several farmers stated that they resented being obliged to control the noxious weeds in the retired areas.
- Seven out of 17 farmers reported they had done nothing to control weeds in the retired areas (despite their obligation to do so); two had no problem and eight had undertaken some weed control.
- Farmers reported that retirement has had only minor effects on day-to-day management. Some reported stock mustering was easier because of the retirement fencing and some reported reduced stock losses in the stream.
- Seven of 17 considered their property value had probably been affected by the retirement works; five of those felt it had declined because the retired areas were a mess to look at or they had lost significant grazing areas to retirement, while two thought their property values would increase because the retirement trees are or will be attractive.
- Some were unsatisfied with funding arrangements for maintenance works in the retired areas.
- The majority were satisfied with the way the regional council staff had dealt with them.

Several key issues arose out of these findings. Some of them are positive:

- Farmers were generally concerned about the condition of Lake Rotorua and Ngongataha Stream, and were willing to cooperate in an endeavour to protect them.
- Many of the established farmers felt closely involved in the scheme because council staff had gone to considerable efforts to work in a cooperative manner when designing the farm retirement and planting plan. They appreciated being able to participate in species selection and placement of fences, etc.

There were also some negative issues identified:

- Most of the farmers lack any sense of responsibility for the retired areas. While most had retained title to the land, it was viewed as unproductive and consequently an unwarranted drain on resources. This attitude was especially noticeable amongst those who had purchased the properties after the works were completed.
- Several recent purchasers of property appeared unaware that they were responsible for maintaining the retired areas.
- There was a general level of discontent with funding arrangements for maintenance works and an unwillingness to make substantial efforts to control the weeds that are proliferating along stretches of the stream bank.
- There was concern about the lack of funding and arrangements for replanting where initial plantings have been unsuccessful.
- There has been reinforcement that the original preference for native plants over exotic species should be adhered to along riparian margins now that native plants are readily available.

Riparian management today in the Bay of Plenty

The Bay of Plenty Regional Council has learned a lot from the experiences of the 1980s and has adapted its riparian and soil conservation procedures accordingly.

Farm plans

The Regional Council (Environment BOP) remains one of the few regional councils who continues to offer farm plans supported by a grant rate funding system. It offers a two-tiered free farm plan service to farmers:

1. Soil Conservation Plans, which focus on on-farm erosion issues and remedial or preventative works.
2. Environmental Plans, which have a broader focus and allow grant funding to be used in support of works including bush and wetland retirements and soil erosion control. These plans cover issues such as:
   - runoff control
   - erosion control
   - protection of natural areas (wetlands and bush areas)
   - waste disposal
   - fertiliser use
   - plant and animal pest control.

Funding assistance

The Council provides grant rate assistance of 50 percent for works with a high off-site benefit, including retirement fencing, retirement planting and erosion control structures. Twenty-five percent assistance is provided for works with moderate off-site benefits such as alternative water supplies, woodlots and spaced planting.

Assistance has been reduced from the 87 percent-plus-compensation high of the 1980s for several reasons:

- *affordability*: making the ratepayer dollar go further
- *equity*: a 50:50 split symbolises a balanced partnership
- *ownership of responsibility*: past experience has shown that high grant rates do not create commitment, motivation or any sense of ownership
- *incentive:* having a grant rate of any sort encourages more environmental protection work to be done than would regulation or recommendation alone.

Landowners who receive grant assistance for retirements or major works are required to accept a Land Improvement Agreement which is registered against the land title and applies for 99 years. The essential conditions of an LIA are that no earthworks are disturbed, that no stock are grazed in retired areas and that maintenance is the responsibility of the landowner.

Environment BOP has a policy of offering its services only to those who request it. The farmer must make the first approach.

Glossary

Baseflow	Flow sustained by groundwater inflow.
Biochemical oxygen demand	Indicator of the strength of a waste; a measure of the oxygen required by micro-organisms to decompose organic material.
Contaminants	Includes any substance that when discharged into water or onto land, changes the physical, chemical or biological condition of water/land, with harmful or potentially harmful effects. (Abbreviated from the RMA)
Denitrification	Reduction of nitrates to nitrites, nitrous oxide or nitrogen under anaerobic conditions.
Dissolved oxygen	Oxygen dissolved in water.
Enterococcus bacteria	Large family of bacteria, that can grow in the presence or absence of air.
Eutrophication	Process of nutrient enrichment in aquatic ecosystems; occurs naturally over geological time, but may be accelerated by human activities.
Faecal coliform bacteria	Bacteria present in the intestines of humans and other animals, indicative that water has been contaminated with faeces.
Flow regime	A description of flow magnitude over time.
Kaitiakitanga	The exercise of guardianship, including the ethic of guardianship.
Macrophyte	Large vascular, rooted plants and bryophytes.
Mahinga kai	Food sources.
Mauri	Life force. (No direct translation to English.)
Periphyton	Non-vascular plants forming crusts, films or filamentous mats in the river.
Phytoplankton	The plant plankton and primary producers of aquatic ecosystems.
Pugging	Destruction of surface structure of wet soils by stock or traffic.
Rahui	Restriction or enforcement over a resource as a means to enhance the mauri of that resource.
Riparian management	Management and enhancement of land and the water that runs over and through the riparian zone or directly influences a body of water.
Riparian vegetation	Plants uniquely suited to the zone between aquatic and terrestrial ecosystems.
Riparian zone/area	Land that adjoins or directly influences, or is influenced by, a body of water; an area where water accumulates periodically.

Tiaki	Guardian or guardians, of an area of land or a waterway.
Turbidity	Cloudiness in a liquid caused by the presence of finely divided, suspended material
Waahi tapu	Sacred place or location.
Wai taonga/Wai tapu	Sites of special spiritual significance.