# An evaluation of the ecology and riparian management of the south branch of the Whareroa Stream, Paekakariki

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# Abstract

Whareroa Farm, Mackays Crossing, Paekakariki, was bought by the Department of Conservation in 2005. The goal was to effect the restoration of a corridor for flora and fauna from the Akatarawa Forest in the east to Queen Elizabeth Park and the sea in the west. The south branch of the Whareroa Stream, which arises as a series of tributaries from a ridge 272m above sea level, traverses Whareroa Farm and the adjacent Queen Elizabeth Park. It was thought likely that the stream had been severely affected ecologically during a century of cattle and sheep farming, though the degree to which the ecological degradation had occurred was unknown. Obvious deforestation and land use changes suggested that, in concert with many other New Zealand hill country farms, the ecological changes would be significant.

To establish and quantify the degree of degradation, the Auckland Regional Council (ARC) Stream Environment Valuation (SEV) protocol was applied to the Whareroa Stream and its tributaries. Five sites were selected for valuation, varying from open pasture to bush covered and open parkland. The resulting SEV scores showed losses of ecological value ranging from 32% to 46% across the sites.

The Macroinvertebrate Community Index (MCI) and the fish Index of Biological Integrity (IBI) were measured at each site. Results indicated that aquatic habitats were unable to sustain adequate assemblages at four of the five sites.

The valuations of the riparian zones at each site used the River Environment Classification (REC) and Riparian Management Classification (RMC) protocols. The results indicated that current riparian characteristics showed poor to absent effective riparian zones from the headwaters to the sea at all sites. Riparian zones are pivotal to the provision of stream ecological integrity and are responsible for maintaining the longitudinal, lateral and vertical connectivity between a stream, its network and its surrounding land. The loss of in-stream organic matter from lack of riparian vegetation together with the loss of effective temperature control from lack of shade, impacts negatively on the habitats for macroinvertebrates and fish. This was highlighted in the Whareroa Stream network.

While the SEV and RMC evaluations showed that, with best practice management plans, there was great potential for improvement of the Whareroa Stream ecology, any riparian restoration would require sympathetic and improved fencing, withdrawal of stock from stream access and the retirement of headwater land from pastoral use. The loss of ecological integrity that occurs as a result of prolonged land use changes from forest to agriculture is well illustrated by the situation in the south branch of the Whareroa Stream and its tributaries.

## Explanation of text

This thesis will be presented as two papers with a general introduction. Some of the information will be presented in both Chapters 2 and 3 where this is relevant. Inevitably this will lead to some repetition.

## Acknowledgements

Particular thanks to Dr Mike Joy, my supervisor, who suggested this study and then advised, encouraged and supported me for its duration, including the statistical manoeuvres and computing errors I seemed to attract.

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# Chapter 1
# General Introduction

Whareroa Farm, Paekakariki, (coordinates 40° 58'32. 5"S, 174°59'21. 4"E) covers 447.5 hectares comprising a mixture of steep hill country. The adjacent Queen Elizabeth Park covers 646 hectares of dune lands and peat soils, has some remnant wetland bush and swamp areas but is mainly drained grassland and low scrub (Mackay, 2007).

First and second order streams, arising in the hill country, run west to form the south branch of the Whareroa Stream near Mackays Crossing. The stream then flows through a culvert, beneath State Highway 1. Several farm streams join it over the next 1.5 km in Queen Elizabeth Park before it reaches its confluence with the north branch to form the Whareroa Stream. The stream continues for a further kilometre through the peat swamps and sand dunes to the sea.

The Department of Conservation (DOC) purchased the Whareroa Farm from Landcorp in 2005, a purchase strongly supported by the community who promoted it as a corridor for wildlife and thus a link from the Akatarawa Forest in the east to the sea in the west. Farming over the last century had caused irreversible damage to the streams and valleys, and changes to the stream ecology associated with road works and culverting at Mackays Crossing were unknown. Riparian zone management had been non-existent on the farm apart from small areas near the shepherd's house and the farm entrance. Plans for riparian restoration on the lower reaches of the Whareroa Stream in Queen Elizabeth Park and the entrance to Whareroa Farm had been developed and were being implemented (WRC, 2004).

**Landform and landscape**

The greywacke that the Whareroa Farm is based on was formed about100 million years ago (Fleming, 1961). Erosion, flooding and the rise of the Tararua Mountains limited the formation of the landform. The onset of Ice Ages and Interglacials over the last one million years was associated with further mountain growth, rivers carrying gravel now found in deposits on the Kapiti Coast, and evidence of cold climate tussock grasslands. Sea levels rose and fell with each glacial period, changing the site and shape of the coastline. Various plants also established and many became extinct eg. *Nothofagus spp.* (Fleming, 1961). Volcanic ash, from a devastating eruption of Lake Taupo 26,000 years ago, covered the land.

The last and most severe glacial period was 20,000 years ago. The retreating sea exposed thick sand and gravel and loess was blown to the hills and Tararua Mountains. The return of the sea when the interglacial period began 11,000 years ago resulted in sand and seashell deposition, and the formation of peat swamps along the coastal region. The peak of the sea level rise was 5,000 years ago as evidenced by the carving of a cliff (along SH1) that marks the post-glacial shore. The rise of the hill country and mountains continued with Mt Wainui reaching 799m above sea level. Erosion of Mt Wainui formed the Te Ramaroa Alluvial Fan visible at the western boundary of Whareroa Farm. Sand dunes and swamps formed over debris flowing south along the coast from the Manawatu and Wanganui rivers.

Further deposits of volcanic ash that can be seen in road cuttings followed another eruption of Lake Taupo 1800 years ago. With climate stability, mixed broadleaf-podocarp forests were established on the hills and forests of kahikatea (*Dacrycarpus dacrydioides)* and nikau palms (*Rhopalostylis sapida*)) on the swamps and flats (Edwards, pers. comm, 2007)

The landform has been altered by activities on the Ohariu Earthquake Fault that passes along the edge of the ancient sea cliffs between Whareroa Farm and Queen Elizabeth Park (Adkin, 1951). This fault is part of a longer fault line that is continuous from Tongue Point (Cook Strait) to Waikanae (van Dissen *et al.*, 2003; Heron *et al.*, 1998). The frequency of movement on the fault is 1530-4830 years and the last recorded movement was 1070-1130 years ago. There is both vertical displacement of up to 2m and dextral horizontal displacement of 7m found near Mackays Crossing (Stevens, 1974).

**Figure 1.** Whareroa Farm from SH1 at Mackays Crossing.

**History of farming at Whareroa**

Whareroa Pa was sited 5 km north of Paekakariki and at the mouth of the Whareroa Stream. By the late nineteenth century the NZ Government had purchased land around the Pa for farming and it quickly lost its inhabitants to other communities. The land east of the Pa had wetland forests, mainly kahikatea, a rich birdlife, and heavily forested hillsides stretched up to the Akatarawa Forest (Edwards, pers. comm., 2007). Utu Pa sites are found on the hills above the wetlands.

A railway from Wellington to Foxton was established in 1886 along the base of the hills, more land was opened up for development, and dune wetlands and lakes were drained. The wetland forests were cut and burned and the hillsides were cleared of bush. Settlers established small farms, for cattle and sheep.

In 1942, the NZ Defence Department took control of most of the farms as part of the WW2 effort to provide facilities for the United States Marines. Camp Mackay was established on the Te Ramaroa Alluvial Fan above SH1, and Camps Paekakariki and Camp Russell on the dune lands. Farm streams from the higher hill country were drained into a reservoir on the lower hill country (still functional for farm water) and water was piped around the Camps. The land reverted to farming at the end of WW2, and was administered by the Department of Lands and Survey.

The small farms east of SH1 were amalgamated to form the Whareroa Farm in 1947. The western portion was gifted to the Queen during her visit in 1953 and named Queen Elizabeth Park. The Whareroa Farm has supported a wide range of activities since then including dairy farming[1]. It was initially open to the public as a farm park, with walking tracks and a picnic area. These facilities have fallen into disrepair and it is no longer open to the public. It was subsequently a stud farm for Charolais and Simmental cattle and supported Romney sheep.

In 1987 the administration of Whareroa Farm was transferred to the State Owned Enterprise (SOE), Landcorp. Their intention was to sell blocks for housing development but in 2006 the Crown was persuaded to purchase the farm as part of the Department of Conservation (DOC) estate. Local Iwi, 'Friends of Queen Elizabeth Park' and 'Guardians of Queen Elizabeth Park' all expressed a desire to co-manage the farm site with DOC. In particular, Iwi wish to preserve the Utu Pa sites within the area. To date no future management plan has emerged for the farm and little is known of its potential for restoration as a bush/ forest corridor from the Akatarawa Forest. Suggestions for future use have included the development of walking and biking tracks to connect Campbells Track with Te Araroa Walkway, the Akatarawa Forest and the Maungakotukutuku Valley (see Map 1); the establishment of a farm park once again; and an upgrade to a self-sustaining farm again.

**Stream Ecological Assessment**

The ecological functions of the aquatic ecosystems of the upper Whareroa Stream and its tributaries were unknown though whitebait, galaxiids (*Galaxias spp)*, eels (*Anguilla*

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[1] Land Utilisation Classifications for Whareroa Farm (2007) were: [1] greywacke ridges up to 235m above sea level, with steep valleys - LUC VIIe1 – (steep to very steep, susceptible to sheet, scree and soil slip erosion); [2] rolling hills with loess over greywacke - LUC VIe3 – (moderately steep, prone to surface erosion); [3] rolling downs prone to surface erosion formed from loess over consolidated gravels - LUC IVe1.

*spp*), bullies (*Gobiomorphus spp*) and shrimps (*Paratya sp.*) had been found in the lower reaches in Queen Elizabeth Park (Joy, 2005). As in a study of headwater streams in the Wairarapa by Macdonald (2006), it was presumed that the stream health of the upper reaches of the Whareroa Farm streams would have been compromised by the farming practices of the last century to such an extent that the changes to the ecology, stream bank quality and riparian vegetation would have adversely affected the populations of macro-invertebrates and fish.

The Stream Ecological Valuation (SEV) method for scoring a stream's ecological structure and function, first developed for Auckland streams by Rowe *et al.* (2006), was seen to be the appropriate tool for the Whareroa Stream evaluation. It is a multi-variant approach that combines 16 variable measurements into a single comparable measure by scaling values for each variable, and then weighting them according to their relative ecological importance. The method is guided by the development of algorithms and provides an overall measure of the ecological function of the target stream.

Four major ecological functions and their components form the basis for the SEV – hydraulic functions (ie. processes for water storage, transport and movement), biogeochemical functions (ie. water chemistry and the processing of minerals and particulate matter), habitat provision functions (ie. types, amount and quality of habitats for stream fauna and flora) and native biodiversity functions (ie. presence of expected diverse populations of fauna and flora within the stream reach).

Though the SEV method had been developed for a specific network of urban streams, it was subsequently successfully used by Macdonald (2006) for the ecological valuation of small rural streams in the Wairarapa, where the effects of agricultural land use on their ecosystems were measured providing a baseline for future monitoring of ecological changes. More recently Phillips *et al.* (2006) used it in Papakura to rank streams in terms of their ecological priority. It was thus apparent that the method could be successfully applied to streams in a variety of environs and that its use for the ecological valuation of the Whareroa Stream was appropriate.

**Riparian assessment**

The Riparian Management Classification (RMC) tools developed in Canterbury (Quinn, 2003), provided excellent adaptable templates for evaluating the riparian potential for the Whareroa Farm streams. The RMC is a development of the River Environment Classification (REC) system (Snelder *et al.*, 1999), and uses the REC classifications within the template. The Riparian Management Classification – Current (RMC-C) and Riparian Management Classification - Potential (RMC-P) have been used on large and small streams by Regional Councils throughout New Zealand to provide a basis for riparian management (Phillips & Marden, 2004; Quinn & Suren, 2001; Quinn *et al.* 2001).

The RMC protocol is based around the activity of 12 riparian functions seen as essential to improving stream habitat, controlling contaminant input and enhancing biodiversity, aesthetics and recreation. The key factors influencing potential riparian functions identified in Canterbury were stream width, adjacent land slope and whether the stream was ephemeral or perennial. A geomorphic RMC (RMC-G) was derived from the riparian functions giving further detailed classification for future management, including valley-form and vegetation types appropriate to stream width. These details will be important to restoring the Whareroa Farm streams.

Until recently the Farm has been used for the fattening of young Angus cattle and sheep. There is obvious damage to stream banks and hillsides with some slipping. Many fences are intact but bear no relationship to the streams or bush remnants and animals have crossed the streams and accessed the bush remnants freely. The farm also supports a significant feral population of goats, rabbits, hares, and large numbers of possums. Weeds are extensive with large areas of gorse and variegated thistle. Some of the higher land has scrub and regenerating native bush, and the moderate hill country has bog and swamp areas scattered throughout it. Remnant stands of bush include kahikatea (*D. dacrydioides*), nikau (*Rhopalostylis sapida*), mahoe (*Melicytus ramiflorus),* kohekohe (*Dysoxylum spectabile*), titoki (*Alectryon excelsus*), kawakawa (*Macropiper excelsum*), karaka (*Corynocarpus laevigatus*) and a few tree ferns, depending on their South-Easterly aspect (Figure 2). A stand of gum trees is present on the northern side of the farm.

**Figure 2.** Remnant bush in a central valley, Whareroa Farm.

**Future plans**

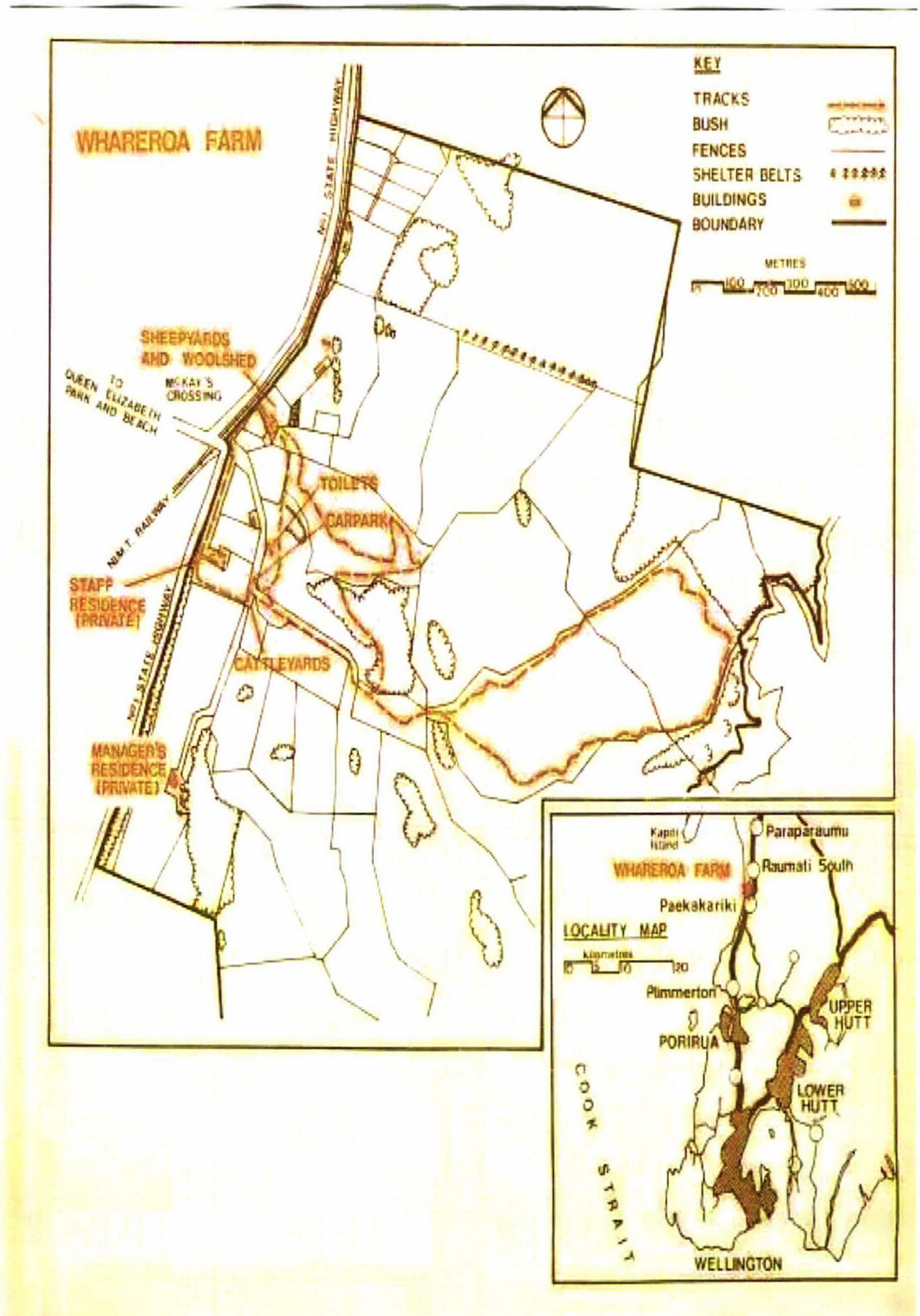
This baseline study looked at the ecological and riparian health of the streams on the Whareroa Farm in order to provide a contribution to the overall planning for the farm. Its focus on the ecological valuation and riparian conditions of three representative streams that form the south branch of the Whareroa Stream, and the two stream sites in Queen Elizabeth Park that were also surveyed, provided an indication of what fauna and flora could be expected with any future upstream enhancement. The results of both valuations, though not surprising, were not surprising given the current and past history of bush removal and intensive farming of the area.

The use of the Stream Ecological Valuation (SEV) method to provide baseline ecological information represents further experience with this method in establishing a nationwide standard procedure for ecological valuation of stream ecosystems, a position already held for the Riparian Management Classification (RMC) that was also used in the study. Restoration of the stream will involve improved stream connectivity in all the longitudinal, lateral and vertical parameters, and long term planning and monitoring of small but cumulative restoration projects. Re-establishment of riparian zones from the catchment to the sea will assist with the improvement of stream conditions, though it cannot be assumed that invertebrates and fish fauna will necessarily re-occupy any particular habitat (Hildebrand, R.H. *et al.*, 2005; Lake, P.S. *et al.*,2007)

The SEV and RMC results for the Whareroa Stream will lead to decisions that have financial implications for the community, Greater Wellington Regional Council and the Department of Conservation when determining the costs and potential for improved functions.

The findings are presented as two papers. The first is a stream ecological assessment, and the second an assessment of the riparian situation.

**Map 1. Whareroa Farm, 1983.** (Department of Lands & Survey publication)



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# Chapter 2
# The Whareroa Stream – an ecological valuation

The goals of sustainable stream and river management are to ensure that the function and structure of the waterways are the same, or as similar as attainable, to their or similar un-impacted catchments. The health of the network depends on the balance between these various forms. Structural indicators measure the chemical services provided by ecosystems, the composition of the invertebrate and fish communities, and macrophytes and algae. Functional indicators measure the hydraulic functions, water quality, and focuses on primary productivity and organic matter decomposition. Disruption of either, or both, the structure or function occurs with land use changes. These changes may occur over time cumulatively or rapidly and destructively. The major factor identified in numerous studies is deforestation where biogeochemical, hydraulic and habitat provision are all disrupted or destroyed (Young *et al.*, 2004).

**Ecological integrity**

The term 'ecological integrity, a term describing the condition or health of a network of streams, was first introduced under the USA Clean Water Act, 1972 (Karr, 1981). It is usually defined according to human concepts of human health, and indicators of health have been devised along these lines. These concepts of health have the common theme of maintaining structure and function and of an absence of stress within the stream network. Indices of ecological integrity have been developed for evaluating species richness (fish and invertebrates), using indicators such as pollution-sensitive taxa and the relative abundance and/or dominance of particular taxa (Karr, 1981, 2005).

However, Jansson *et al.* (2007) have drawn attention to the need to recognise that ecosystem structures and function are complex and that any undertaking to restore an ecosystem involves not only the target area but also the connectivity with surrounding landscapes. Thus, components of ecological integrity will be reflected in the index of biological integrity (IBI) for communities eg Fish IBI.

Baron *et al.* (2002) identified five characteristics of streams that drive their ecosystems, namely: (1) flow regime; (2) organic matter input; (3) temperature and light; (4)

chemical and nutrient input; and (5) biotic assemblage. They are inter-related and connected such that any evaluation of an ecosystem must consider them together. These drivers are pertinent to the Whareroa Stream both on the Whareroa Farm and in Queen Elizabeth Park, where the potential for restoration of forest to land that has been farmed for more than a century relies on the current integrity of the streams and riparian zones, the potential for mitigation and restoration, and future practical land-use management decisions.

Streams afford small-scale processes within the over-arching physical factors affecting waterways such as climate and geomorphology, and are pivotal in determining flow characteristics and species interactions. Their riparian ecosystems protect against erosion and flooding, contribute to nutrient input and assist with water temperature control.

There has been recent acknowledgement that biologically intact freshwater ecosystems benefit humans both short and long term (Edward-Jones *et al.* 2000). The structure and function of aquatic ecosystems are the links between the catchment and their ultimate destinations (lakes, wetlands, rivers or the sea). They provide the dynamic goods and services produced by the ecosystem and are thus influenced by modifications to land use and human needs (Baron *et al.*, 2002).

**Assessing human impacts**

A variety of studies in New Zealand (Quinn & Hickey, 1991; Harding & Winterbourn, 1995) and overseas (Saunders *et al.*, 2004) have identified that stream ecological "health" is a whole catchment land use issue. The downstream effects of human interference at any part of a stream network can have ruinous results for associated ecosystems. Dramatic changes to stream hydrology will affect water quality, physical habitat and biotic interactions, and include deforestation of catchments and riparian zones, land use changes to agriculture or urbanisation, wetland drainage, straightening of farm streams, barriers to flow such as culverts, and denial of fish and aquatic invertebrate access from in-stream structures including dams and weirs (Collier, 1993; Joy & Death, 2004). Consistently, there are findings of reduced taxonomic richness in streams draining farmlands as compared with those from bush and forested lands (Harding & Winterbourn, 1995; Thompson & Townsend, 2004).

**Fish communities**

Land use changes affect both macroinvertebrate and fish communities, and macrophyte and periphyton growth (Biggs, 1989). An assessment of east coast streams of the North Island of New Zealand showed a marked mal-distribution of galaxiid species between and within first and second order streams in different land uses. Of the six fish species studied, galaxiids such as koaro (*Galaxias brevipinnis*) and banded kokopu (*G. fasciatus*) were more common in native and exotic forest streams, but shortfin eels (*Anguilla australis*) and inanga *(G. maculatus*) were more common in pastoral areas (Rowe *et al.*, 1999). A survey of a Waikato pastureland stream with high nutrient concentration also showed domination by shortfin eels and an absence of galaxiids (Hicks *et al.*, 2001). Many studies have found that enrichment-sensitive macroinvertebrates, such as Ephemeroptera, Plecoptera, and Trichoptera (EPT) species, are replaced by more enrichment tolerant ones such as molluscs, crustacea and chironomids (Harding & Winterbourn, 1995; Quinn *et al.*, 1997; Harding, 1999; Thompson & Townsend, 2004; Death & Collier, 2007).

**Invertebrate communities**

New Zealand streams are characteristically subject to a non-seasonal climate where rainfall occurs year round, flash flooding is unpredictable, non-deciduous native forest is a poor supplier of leaf litter and woody debris, and there is considerable asynchrony of emergence among the stream macroinvertebrates. Thompson (2000) considers that this has resulted in a resilient opportunistic fauna with a lack of ecological specialization, and life history flexibility. He illustrates the point with reference to two features - (a) a small group of macroinvertebrate species found across a variety of settings, eg ubiquitous *Deleatidium spp.* and *Potamopyrgus spp.*, and (b) a few species found in high densities within different land uses eg (i) chironomids in pasture streams with high turbidity, (ii) trichoptera (*Olinga feredayi*) in tussock-land streams and (iii)) stoneflies (*Austroperla cyrene*) and black flies (*Austrosimulium spp.*) in bush streams.

The anthropogenic changes in land use with their widespread disturbances to freshwater ecosystems and clean water have been largely responsible for the development of local NZ biotic measures to address and monitor water quality. Biotic indices have superseded chemical indices as measures of clean water in many regions worldwide. Karr (2005) noted that in one example cited by Davis *et al.* (1996) in their '*Summary of*

*State Biological Assessment Programs for Streams and River*', chemical evaluations failed to detect 50% of the damage to surface waters when compared to the more sensitive biotic methods.

**Assessment methods**

As ecological health of streams is the result of a combination of ecosystem structure and function, each of these elements has been widely researched, structure more than function. Ecological structural attributes, such as quantitative and qualitative assessments of ecologic communities and their resources, are referenced to pristine conditions for comparison with the actual site being studied. Ecological function attributes, which evaluate ecosystem processes such as primary production and oxygen consumption, are qualitative and unreferenced (Gessner & Chauvet, 2002).

There are a number of methods available for the assessment of the structural and functional components of stream ecological integrity. The main ones are summarised below.

**Structural Assessment**

The transformation of rural land use from forest and tussock to agriculture in New Zealand has now reached 51% of the total land mass representing a very significant threat to the ecological integrity of streams and rivers throughout the country (Quinn *et al.*, 1997). The ecosystem structural stresses are reflected in reduced populations of sensitive taxa, increased invertebrate densities, increased periphyton and macrophyte mass and changes to fish communities (Winterbourn, 1986; Townsend *et al.*, 1997; Quinn *et al.*, 1997; Harding *et al.*, 1999; Rowe *et al.*, 1999).

Whareroa Farm is likely to be no exception to this general tenet. The single metric (MCI), multimetric (IBI), and multivariate predictive model methods of assessment (point click fish) provide insights into structural dysfunction.

**Metric assessments**

In New Zealand, biologic indicators for clean running water and stream health have focused on the use of the ubiquitous macroinvertebrates as indicators of the condition of fresh running water. The Macroinvertebrate Community Index (MCI) (Stark, 1985) was developed as a tool for assessing the nutrient enrichment of stony bottomed streams on the Taranaki Ring Plain but is now widely used by all Regional Councils.

The metric used is the tolerance score of the macroinvertebrates found where the most pollution-sensitive taxa have a higher score (*Helicopsyche* = 10, *Chironomus* = 1) (Appendix 4). The MCI is a non-quantitative index derived from these scores and gives an evaluation of the degree of pollution of a stream, with the higher indices indicating better stream health. If the most sensitive taxa (Ephemeroptera, Plecoptera, and Trichoptera (EPT) species) were expected to dominate but were sparse or absent, this would provide evidence that there had been a change in the community composition in the stream, and particularly if there was also dominance by Mollusca, Crustacea, Chironomidae, and Oligochaeta (Wright-Stow, 2003).

The advantage of the MCI is the ease with which it can be performed, requiring minimal equipment, and no laboratory facilities, as identification usually goes down to genus only in the field. The NZ Macroinvertebrate Working Group developed protocols for sampling macroinvertebrates in wadeable streams (Stark *et al.*, 2001) to ensure standard procedures that would minimise variability in data collection (Stark, 1993).

One difficulty in assessing stream health is that using the MCI alone does not necessarily identify that stream fauna are immediately reacting to the stresses and influences on the ecological function of a stream (Nelson, 2000). Macro-invertebrate communities may take some time to change their structure under stress as was shown in an Australian study in forested streams where stream metabolism was markedly affected by increased turbidity and increased nutrient levels, but the macroinvertebrate community appeared unchanged (Bunn & Davies, 2000). There has been debate as to exactly what the MCI and the Quantatative Macroinvertebrate Community Index (QMCI) indices measure relating to pollution, as they are not always identical in interpretation of the results (Stark, 1998; Wright-Stow & Winterbourn, 2003).

Other tools that have been developed to measure invertebrate community structure include the MCI derivative QMCI (Wright-Stow & Winterbourn, 2003); species evenness (Death & Winterbourn, 1995); proportion of sensitive taxa present (Quinn *et al.*, 1997); species composition (Harding , 1999) and taxa richness (Quinn *et al.*, 1997).

**Multimetric assessment**

The Fish Index of Biologic Integrity (IBI) is a multi-metric index that has become established as an essential index of clean water (Joy & Death, 2004; EPA, 2007). It is based on the presence-absence of predicted taxa. The metrics used to assess the freshwater fish assemblages in New Zealand streams differ from those used in the Northern Hemisphere, as there are a smaller number of species, and high diadromy is usual. The strength of the IBI as a measure of habitat quality has, therefore, been called into question since many features other than habitat quality may contribute to changes in a fish community (Joy *et al*, 2000; McDowall *et al*, 2000). Its relevance as a water quality indicator has also been challenged with regard to the small number and limited diversity of fish species (McDowall & Taylor, 2000).

However, Joy & Death (2004) were able to show, using a multi-metric approach, that species richness in NZ streams is a function of altitude and distance from the coast. The six metrics used were 'the number of native species, the number of native riffle dwelling species, the number of native benthic pool species, the number of native pelagic species, the number of intolerant or sensitive native species and the proportion of alien species'. The scores for each site relative to their altitude and distance from the sea provided an index of biotic integrity where higher scores indicated better water quality. The recommendation that all sampling be conducted in late summer has recognised that valid surveys of diadromous fish requires them to be in freshwater and this is most likely for all species at the end of summer.

**Functional assessment**

The consequences of changed land use on ecosystem function have been less well studied than that on ecosystem structure. Rates of organic matter decomposition are increased in the presence of agricultural land use, and there is altered ecosystem metabolism including altered respiration and primary productivity (Gessner & Chauvet, 2002). Levels of primary productivity may be affected by the degree of riparian canopy cover, increased turbidity, nutrient enrichment and pH. Measures of the rates of leaf litter breakdown are presently favoured as indicators of ecological functional health

(Young, 2006) though whether 50% leaf mass loss rates or leaf toughness loss rates are more useful is unresolved.

Studies across 65 NZ sites found that leaf mass loss rates did reflect broad differences in ecosystem functioning, but leaf toughness loss responded mainly to microbial decomposition and was negatively correlated to the MCI (Young, 2006). Mahoe (*M. ramiflorus*) leaves, which have a rapid decomposition rate, were used in all sites. NZ macroinvertebrates are not specialised 'shredders' but have generalised dietary requirements often confounding the findings of leaf pack investigations. Nevertheless, the selection of leaves in a stream has been shown to be important for collector-browser invertebrates such as *Olinga feredayi* larvae (Quinn *et al.*, 2000) suggesting that optimal riparian restoration should be selective in its plantings.

Studies overseas have found increased leaf breakdown in pastoral streams where both nutrient levels and macroinvertebrate density are high (Gessner & Chauvet, 2002; Danger & Robson, 2004; Macdonald, 2006). Perceived time constraints, technical difficulties and costs have mitigated against the widespread regular use of leaf packs. Standardisation of parameters reflecting the speed of litter breakdown, the type of leaf used and stream classification are seen as essential developments in implementing the method (Gessner & Chauvet, 2002). The Ministry for the Environment is presently researching methods for use in NZ.

The impacts of human activities on urban stream health in NZ cities in addition to that already identified for rural streams, has led to a more holistic approach to stream ecological assessment. All classes of urban land are being replaced by dwellings,

factories and infrastructure elements such as roads. Streams are frequently culverted, channelised and modified, often with gabions and other barriers, concrete linings and stripped of any riparian zone. Heavy sediment loads of dust from excavation sites maybe wind blown into streams or run-off directly in rainfall events, and drainage from roads and storm water drains is frequently polluted. Changed flow regimes, bank erosion, fewer native fauna and increased macrophytes are indicators of reduced ecological integrity in the urban streams. (Rowe, 2006, Title page).

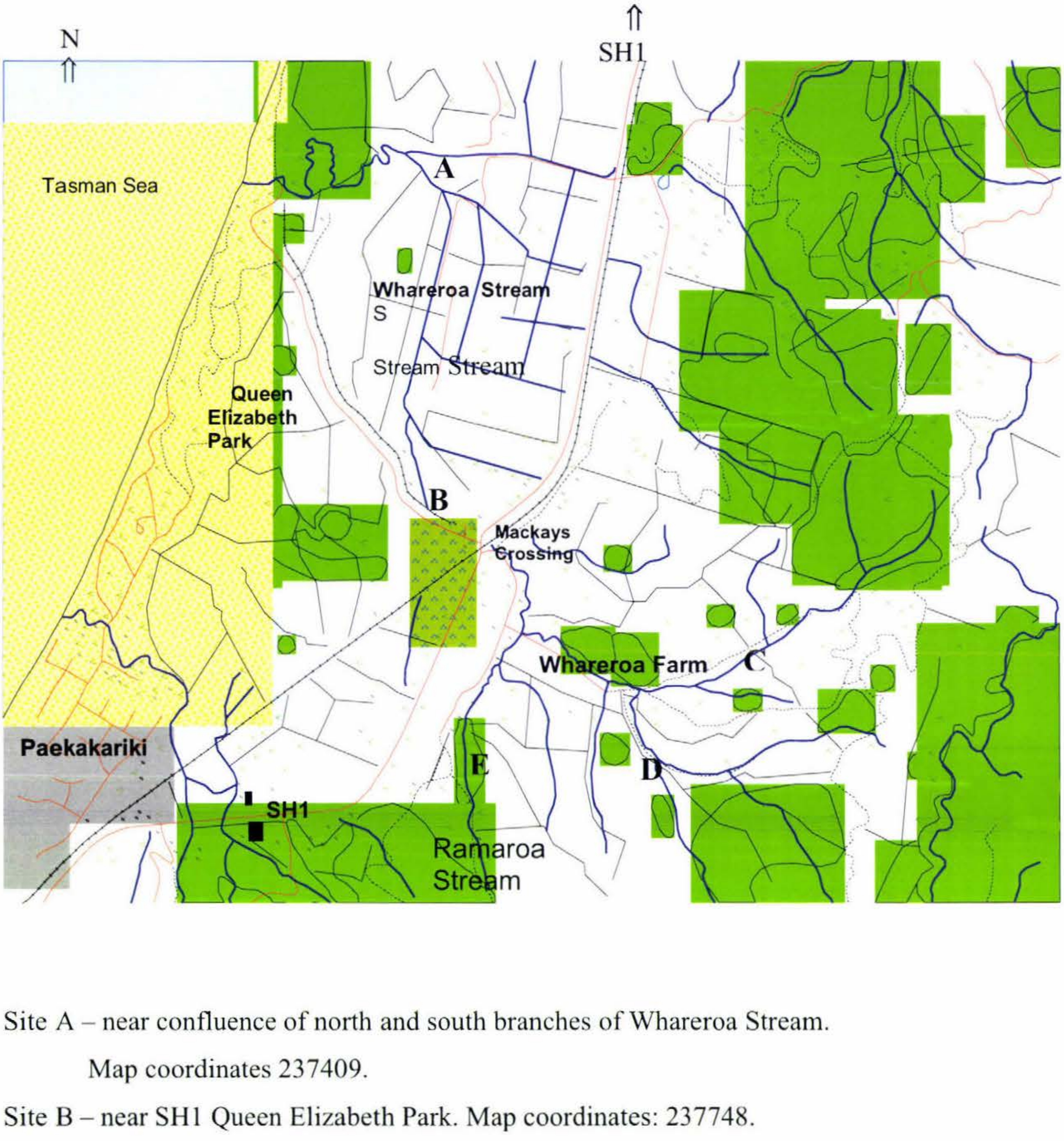
The RMA (1999) requires that the environmental impacts of land use changes and human-induced activities be assessed. This was the driver that resulted in the development of the Stream Ecological Valuation (SEV) instrument for the ARC (Rowe *et al*, 2006). The SEV provided "a method for scoring the ecological performance of Auckland streams and for quantifying mitigation" (Rowe, 2006, Title page). Though developed as a guideline for mitigation, it has wider applications for stream health in other environments. It was successfully used to assess streams in the northern Wairarapa to determine the ecological differences between streams in forested areas and those in pastureland (Macdonald, 2006).

The method compares reference streams with the streams under investigation through a series of functions – hydraulic functions (water storage, movement and transport); biogeochemical functions (related to minerals, particulates and water chemistry); habitat provision functions (type, amount and quality of habitats for flora and fauna) and biodiversity provision functions (occurrence of diverse populations of indigenous plants and animals). The SEV is a melding of the biotic assessments, structural factors and physico-chemical conditions of a stream.

**Aims of study**

The Whareroa Stream and its tributaries have never been evaluated for their current ecological status or their potential for sustaining macroinvertebrates and fish. This baseline study of the south branch of the Whareroa Stream was focused on the functional and structural relationships of the stream and its tributaries, including assessments of the hydraulic, biogeochemical, habitat, biotic and riparian functions.

**Map 2.** Map of study sites (A, B, C, D, E) on south branch of the Whareroa Stream.




Site A – near confluence of north and south branches of Whareroa Stream. Map coordinates 237409.

Site B – near SH1 Queen Elizabeth Park. Map coordinates: 237748.

Site C – on northeast branch of stream, Whareroa Farm. Map coordinates: 237905

Site D – on east branch of stream, Whareroa Farm. Map coordinates: 238253

Site E – on Ramaroa Stream, southern branch of Whareroa Stream, Whareroa Farm. Map coordinates: 238286

Three of the stream sites for evaluation were on Whareroa Farm and two in Queen Elizabeth Park, providing a broad view of the ecological integrity of the streams (Map 2). A small study of the habitat for fish and macroinvertebrates in the lower reaches done in 2005 (Joy, 2005) gave some guidance as to the fauna that might be expected upstream, but recent road works at Mackays Crossing may have compromised the ability of the macro-invertebrate and fish communities to access the farm streams.

Baseline ecological studies provide vital information on the current situation of a stream or network of streams. The functional and structural functions of the stream network depend on the past and recent history of the local environment, particularly changes in land use over time, and the current use of the environment. Assessment of the current situation is, therefore, a springboard or reference for the future monitoring of ecological changes occurring with any new land usage including retirement of land for restoration.

A baseline study is a reflection of the ecological integrity of the entire catchment. It is essential for any restoration project that a monitoring programme is included in the project plan to measure change and thus allow for early intervention and mitigation where adverse effects are noted. The preferred new land use is likely to include sheep farming on the down country, as well as the restoration of the bush in the Whareroa Stream headwaters and riparian zones. The results of this survey will provide the baseline ecological information for the Whareroa Farm management plan.

# Research Methodology

## Study area and selection of survey sites

### The Whareroa Stream

The Whareroa Stream catchment hillside has a base of greywacke bedrock, deeply incised by its streams. The steep valley sides in all areas were eroded by animal tracks and had superficial slipping (Mackay, 2007). Apart from areas near the woolshed and the shepherd's cottage, where the riparian strip was fenced, fencing was unsympathetic to restoration of bush with streams being very accessible to animals. As a consequence, stream banks were broken for up to 2-4 metres at or near crossing points on the hilly sites. The streams carried visible sediment below these areas especially when cattle had recently crossed and after rain. Riparian growth other than grass was sparse for most of the area. A small wetland swamp area was present near the entrance to the farm. Bog and swamp areas on the valley sides were freely accessed by cattle.

The three stream sites on Whareroa Farm and two stream sites in Queen Elizabeth Park selected for investigation of their stream ecological values (SEV), represented the general variations in geomorphology of the Whareroa Stream catchment. These 5 sites provided a comprehensive view of the current and potential ecological valuations of the south branch of the Whareroa Stream (Figures 3-7). All streams were perennial and thus provided potential habitats for macroinvertebrates and fish fauna.

The study reach at each of the sites was 50m long and as straight as the landform would allow (see Map 2). The farm sites C and D were freely accessible to cattle if and when the rotation of animals around the farm used the specific paddocks containing the study site.

Access to the farm sites was agreed to with Ministry of Works personnel working at Mackays Crossing, DOC and the resident shepherd. Access to the stream in Queen Elizabeth Park is unlimited as it had public access, the Ranger having also been informed. Any limitations to the study sites on the farm were determined by stock in the areas or flooding of the streams. Stream invertebrate samples preserved with 10% formalin were taken to the laboratory at the Ecology Department, Massey University, Palmerston North, for identification of the macroinvertebtates they contained using illustrated keys for aquatic and water-associated insects inhabiting New Zealand (Winterbourn *et al,* 2000). The streams were assessed in the spring and autumn to determine seasonal variations in macroinvertebrates, and in the summer and winter to establish changes in fish populations.

## Survey sites descriptions

**Site A:** Site A was a third order, extensively channelised stream within Queen Elizabeth Park 16m above sea level and 1.1 km from the sea. It was upstream of the confluence with the north branch of the Whareroa Stream and received several farm streams above the study site. The stream base was up to 16cm sediment (possibly topsoil) on bedrock which was not exposed. There was abundant macrophyte invasion from water celery (*Apium nodiflorum*) and watercress (*Rorippa nasturtium-aquaticum*). The stable grassy banks were 1.5m high with recent plantings of grasses and shrubs. Fencing to the north and south was more than 50m from the site.

**Figure 3.** Site A, Queen Elizabeth Park

**Site B:** Site B was a partially channelised, third order stream, 19m above sea level and 1.9km east of site A. It had stable banks 1.5m high. The streambed had a cobble base and a moderate amount of macrophyte cover. There was some riparian low scrub on the right bank and mature exotic and native trees on the left (south) bank. The banks stretched on to flat compacted duneland and peat overlain with clay fill to the south and north. The compacted land was a remnant of the USA Marine camps and supports grasses.

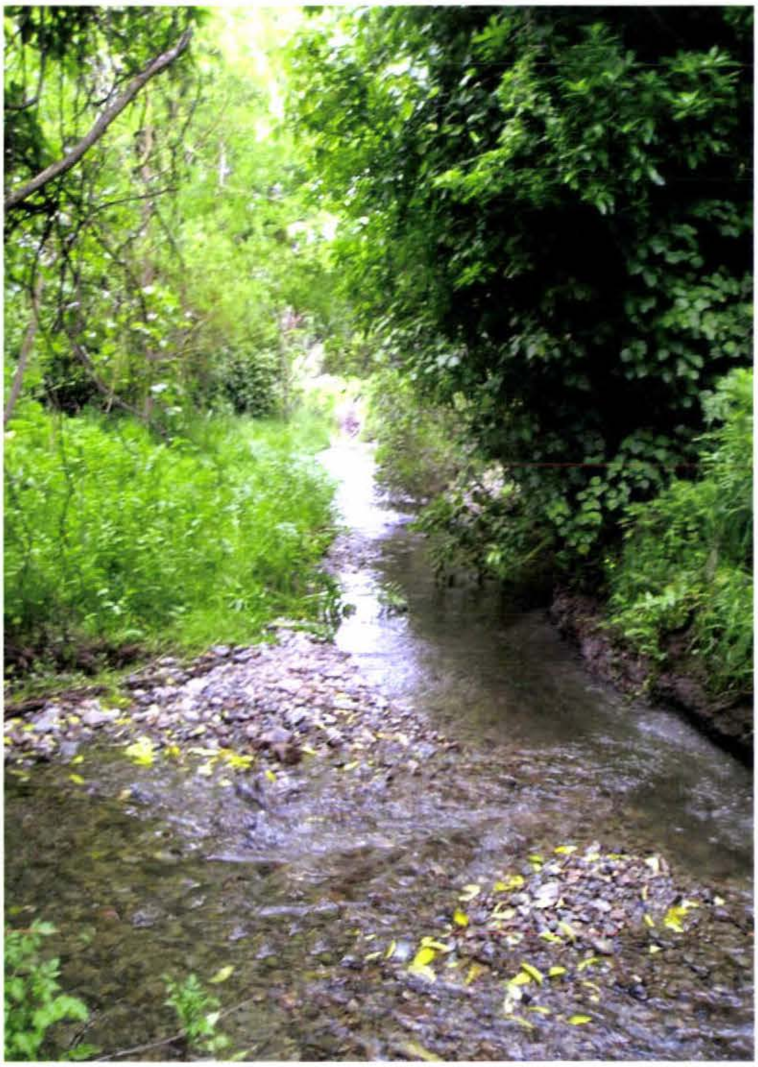


**Figure 4**. Site B, Queen Elizabeth Park.

**Site C:** This site was part of a meandering, first order stream, 161m above sea level, on Whareroa Farm and 5.7km from the sea. It flowed southwest from a ridge 272m above sea level on the Maungakotukutuku hills. Above the site there was steep hill country reverting to scrub (gorse, mahoe and manuka) and a small amount of native bush. The stream base was cobble. There was abundant macrophyte invasion from watercress (*Rorippa nasturtium-aquaticum)*. The stream banks were slumping and cattle damaged (Figure 27).

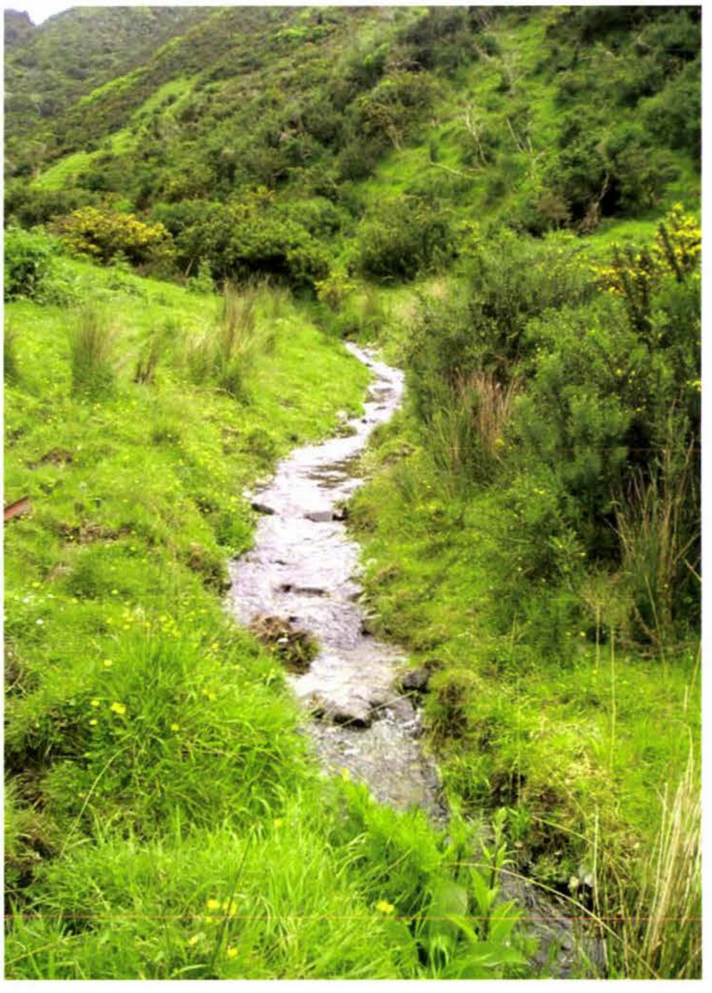


**Figure 5**. Site C, Whareroa Farm

**Site D:** Site D was a second order stream 6.2km from the sea and 154m above sea level. It flowed through a central steep deeply incised valley arising from the eastern hills. Downstream of the reach were large areas of bog on a slumping hillside. The stream had riffles, pools and undercut banks, a cobble base and minimal macrophyte cover. There was no stream cover but the right bank sloped up to >5m high and the 1.5m left bank supported mature gorse >3m high. Water was drawn from the lower end of the reach for the farm reservoir.

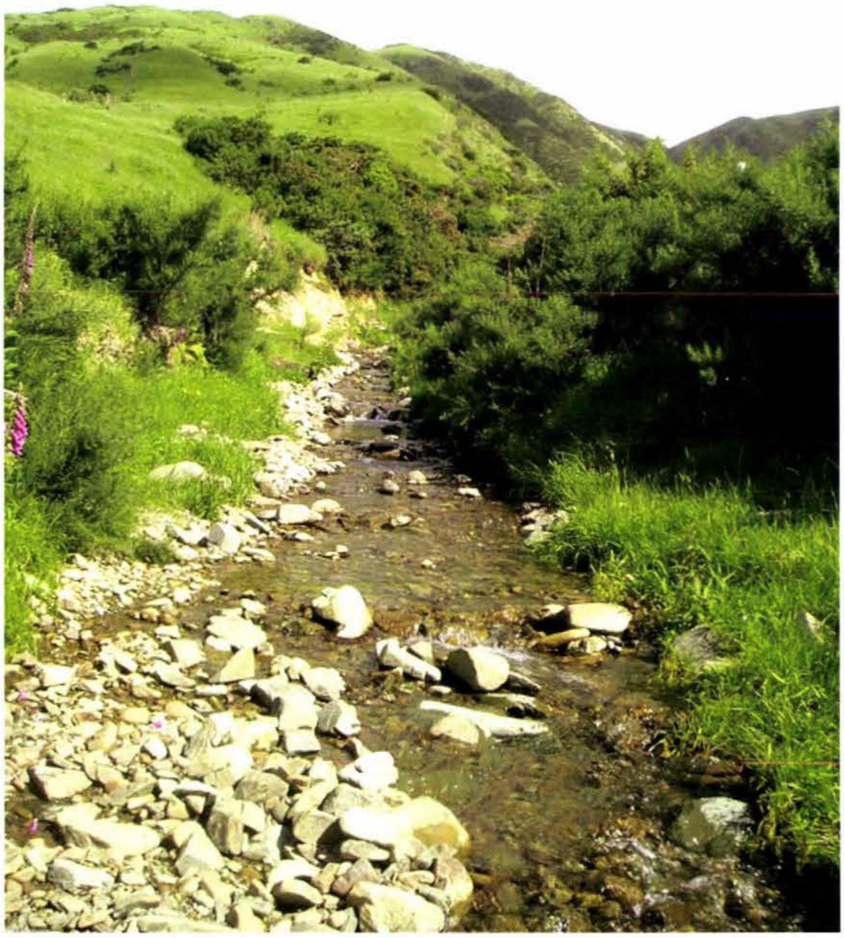


**Figure 6.** Site D, Whareroa Farm

**Site E: (Ramaroa Stream):** Site E was on a second order stream 61m above sea level, 6km from the sea, and on the southernmost tributary of the Whareroa Stream, the Raramoa Stream. The reach had pools and riffles, a cobble base, large amounts of leaf litter and some undercut banks suggesting an ideal galaxiid and bully habitat. The right bank of the stream was >10m high with trees on top, but the left bank was only 1m high and tree covered. The bush area had been fenced off from animals for more than two decades allowing kohekohe (*Dysoxylum spectabile*), matai (*Prumnopitys taxifolia*) and titoki (*Alectryon excelsus*) to regenerate.

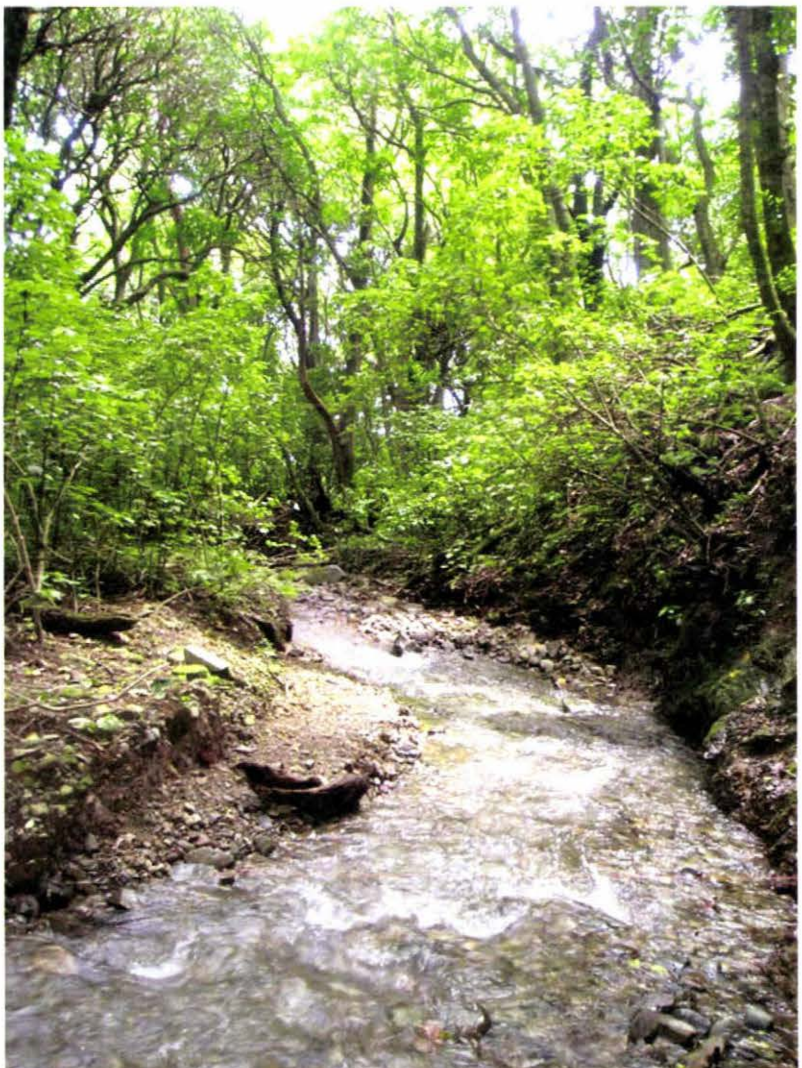


**Figure 7.** Site E, Raramoa Stream, Whareroa Farm.

## Data collection

### Stream Ecological Valuation (SEV)

On-site data collection was made in October-November 2006 at each site. The compilation of data in the field was on worksheets prepared for the location and loosely based around the spreadsheet requirements (Appendix 2). The data was entered on a NIWA EXCEL spreadsheet using the SEV algorithms to calculate the ecological scores for each stream (Appendix 1). It covered the four main ecological stream functions – hydraulic, biogeochemical, habitat provision and biodiversity functions (Table 1).

Scoring the ecological functions followed the methodology adopted in the ARC survey (Rowe *et al*, 2006), where the algorithms had been developed to combine the measurable variables of a stream's ecological function. Each variable was scaled between 0 and 1 and then weighted to reflect its relative importance. The handbook "Stream Ecological Evaluation: a method for scoring the ecological performance of Auckland streams and for quantifying mitigation" was the main source of information in providing the formulae for calculations using direct data.

**Table 1.** Key functions of a stream ecosystem with functional indicators that comprise their assessment (Rowe *et al*, 2006)

| Ecological functions | Functional indicators |
|---|---|
| Hydraulic functions | Natural flow regime (NFR)<br>Connectivity to floodplain (Lateral conductivity) (CFP)<br>Connectivity for species migrations (Longitudinal connectivity) (CSM)<br>Connectivity to groundwater (Vertical connectivity) (CGW) |
| Biogeochemical functions | Water temperature control (WTC)<br>Dissolved oxygen maintenance (DOM)<br>Organic matter input (OMI)<br>In-stream particle retention (IPR)<br>Decontamination of pollutants (DOP)<br>Flood-plain particle retention (FPR) |
| Habitat provision function | Fish spawning habitat (FSH)<br>Habitat for aquatic fauna (HAF) |
| Biodiversity function | Fish fauna intact (FFI)<br>Invertebrate fauna intact (IFI)<br>Riparian vegetation intact (RVI) |

The focus for each function at each site followed the summary chart in Table 1.

The function scores for the five sites were analysed using the spreadsheet formulae and variables. The means of the function scores were expressed as percentages of the possible maximum and provided a view of the type and extent of modification that had occurred.

## Descriptions of functions

### Hydraulic Functions

*Natural flow regime* (NFR): The channel types, the extent of modifications, natural bank erosion and the proportion of upstream imperviousness in the Whareroa Streams network were assessed visually. Changes to natural flows will alter the ecological characteristics of a reach including substrate structure, water flow dynamics, sediment retention and bank erosion.

*Connectivity to the floodplain* (*Lateral connectivity*)*:* (CFP)*:* A floodplain provides an essential foil for diffusing and delaying flood events, retaining sediment and flood deposited vegetation and providing spawning grounds for native fish such as inanga (*Galaxias maculatus*) and koaro (*G. brevipinnis*). The floodplain width and the frequency of flooding were used as indicators of the floodplain's value to the Whareroa Stream's network.

*Connectivity for species migration* (*Longitudinal connectivity*) (CSM): Artificial barriers, such as the Mackays Crossing culvert, may reduce or prevent the annual migration of diadromous fish eg. galaxiids, and aquatic macroinvertebrates eg. shrimps (*Paratya sp*) from the sea to their upstream spawning areas.

*Connectivity to groundwater* (*Vertical connectivity*)*:* (CGW)*:* Disturbances to the streambed affect the hyporrheic zone and impede the processing of nutrients and contaminants.

### Biogeochemical functions

*Water Temperature Control* (WTC): The variables that influence water temperature control in summer include the proportion of shade from the riparian zones and banks, water depth, water velocity, and exposure to solar radiation and ambient air temperature variations. Shade (from trees, banks or structures) for the entire stream above the reach is seen as the most important factor in water temperature control affecting the ecological processes in the streams.

*Dissolved oxygen maintenance* (DOM): As the amount of dissolved oxygen in water determines the organisms that can live in that environment, the scoring for this variable was focused on a visual assessment of the status of the stream substrate and valuation of any oxygen reducing processes present. A stream that is cool and has surface riffles will absorb moderate quantities of oxygen by diffusion but where there is an abundance of macrophytes and algae, the absorbed oxygen and that produced by photosynthesis during the day will be used at night and the water severely oxygen depleted to the point of eutrophication.

*Organic matter input* (OMI): The amount of organic matter, mainly leaf litter, entering a stream from the overhead canopy is an indicator of the production potential of a stream. The contribution from native evergreen and exotic deciduous trees varies with the seasons.

*In-stream particle retention* (IPR): The retention of leaves and debris retaining structures in a stream is critical to the effective processing of organic material by macroinvertebrate and micro-organisms, and will depend on the length of a reach and its flow characteristics.

*Decontamination of pollutants* (DOP): Stream substrates suitable for the growth of micro-organisms (fungi and bacteria) that are able to decontaminate pollutants include leaf litter, periphyton, roots, wood and macrophytes. The composition and structure of the substrates within a reach will determine its potential role as a decontamination site.

*Flood-plain particle retention* (FPR): The ability of flood-plains to sustain ecological values by retaining silt and vegetation loaded during floods is a function of floodplain width, flood frequency, and the structure of the vegetation on the floodplain eg. grass, shrubs or trees.

**Habitat provision functions**

*Fish spawning habitat* (FSH): A key function of streams is the provision of spawning habitats for fish. Galaxiid species deposit eggs on stream banks at high water level among the roots, grasses and shrubs. Bullies deposit eggs on hard surfaces such as the underside of rocks and in-stream wood.

*Habitat for aquatic fauna* (HAF): The physical habitat for fish and invertebrates is created by interactions between many aspects of the physical functions within a stream including low grassy banks, wood debris, leaf litter, cobble and boulders. Important features include the potential for colonisation, stream stability, hydrological conditions, channel shade and the integrity of the riparian zone (Appendix 3).

**Biodiversity vegetation intact**

*Riparian vegetation intact* (RVI): The riparian zone plays a major role in maintaining stream ecological health. It acts as a filter to both surface water and groundwater entering the stream, provides overhead cover, provides wood debris and leaf litter, and maintains aquatic insects. Stream water supports the riparian plants and provides a haven for the larvae of terrestrial and aquatic insects. The land - water interface and interaction is key to ecological health.

*Invertebrate fauna intact* (IFI): An intact invertebrate fauna is fundamental to the conversion of primary production into secondary production in a stream and hence the productivity of fish. The IFI id derived from the MCI of the reach as a proportion of the expected MCI (reference site). .

*Fish fauna intact* (FFI): The fish IBI is a measure of the assemblage of fish within a stream network.

## Structural component indices

### Macro-invertebrate Community Index (MCI), Quantitative Macro-invertebrate Community Index (QMCI), Ephemeroptera, Plecoptera, Trichoptera (EPT) index and Fish IBI

Samples were collected in November 2006 and March 2007, the two collections providing information on any seasonality shown by the local macroinvertebrates. It has been noted that New Zealand does not appear to have the same seasonality associated with its stream fauna that is present in the northern hemisphere. The protocol followed was as described in "Protocols for sampling macroinvertebrates in wadeable streams; Protocol C1: Hard-bottomed Semi-quantitative" (Stark *et al*, 2001)

A D-framed hand net (0.5mm mesh) was used in all sites. It was placed on the streambed and moved upstream slowly in the current for 20 seconds at each transect (about 10m) . Where there was a cobbled/stony bottom, kick sampling and stone disturbance was undertaken, but at all sites the substrate was disturbed. Where possible the samples were taken in riffles (eg. Sites B, C, D, E). In areas with large amounts of macrophytes, these were disturbed for approximately a meter above the sample. Filamentous algae were removed where possible. Where fish were caught these were removed as were large leaves and twigs. The samples were transferred to labelled containers, two thirds filled with stream water and the contents preserved in 10% formalin. The field sheets were completed with date and site details.

Processing of the samples was undertaken at the Ecology Laboratory, Massey University, Palmerston North. The preserved samples were washed through a sieve, usually 0.5mm. The material not required for analysis was returned to the sample container.

The washed sample was placed in a white tray for analysis. Taxa were identified, with the aid of microscopy, using the keys provided by Winterbourn *et al* (2000), and the 'Photographic guide to freshwater invertebrates of Taranaki' compiled by the Taranaki Regional Council. The larvae were then counted and placed in labelled vials. The data was fed into an EXCEL spreadsheet based on the minimum level of identification developed by Stark (1998) (Appendix 4).

The spreadsheet included the MCI tolerance values and identified the EPT taxa. The MCI, QMCI, EPT and taxa count were calculated. The seasonal variation of taxa present was charted (see Appendix 6). The relationship between organic enrichment (water quality classification), MCI and QMCI was charted according to the parameters developed by Wright-Stow and Winterbourn (2003) (Table 2).

**Table 2.** MCI/QMCI. Degradation categories with Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI). (from Stark, 1998)

| Degradation categories | MCI | QMCI |
|---|---|---|
| Clean water | >119 | >5.9 |
| Doubtful quality or possible mild degradation | 100-119 | 5.0-5.9 |
| Probable moderate degradation | 80-99 | 4.0-4.9 |
| Probable severe degradation | <80 | <4.0 |

## Fish IBI

The Index of Biological Integrity (IBI) for fish was calculated from sampling representative sites of a stream network by fish trapping and electro-fishing. The IBI assesses the fish communities after taking into account elevation and distance inland. These are obtained from the River Environment Classification (REC) for the sites. The fish surveys were made in January and May 2007 to ensure that diadromous fish were accounted for in the Whareroa stream network.

### Electro-fishing

Electro-fishing at five transects of each reach 10m apart was undertaken by the use of a portable backpack, pulsed DC electric Kainga EFM 300 NIWA fishing machine. The stunned fish were caught in a fine mesh net just downstream of the electro-fishing operator. The fish were identified, photographed, counted, recorded, and released rapidly with no apparent harm.

### Fish trapping

Three types of fish traps were used. Three 220mm diameter pot-type G-minnow metal traps with 5mm mesh were placed at each site, together with two collapsible nylon pot-type traps of similar mesh. As well as the fish traps at site A, three larger nylon Fyke nets were deployed with the entrance facing downstream and the gate angled across stream. The Fyke nets were 3m long, with 3m gates and had 600mm diameter hoops. Two of the nets had 12mm mesh and the other 2mm mesh. All traps and nets were retrieved after 24 hours, and the fish (including eels) and crustacea removed, identified, photographed, counted and released with no apparent harm.

## Physicochemical conditions

### Temperature variation

Onset Hobo H8 temperature loggers placed at each reach in a deep site measured variability in daily water temperatures. They were removed after 185 days and the information uploaded to assess daily maximum and minimum temperatures. Temperature variability was usually greatest with lack of riparian cover to a stream or seen where there was a dense canopy under which a stream flowed. Where variability was great, the assemblages of fauna might be markedly reduced or absent, and this would be reflected in the MCI and Fish IBI.

### Turbidity

Turbidity occurs as a result of the effect of suspended sediment on light passing through water. It was measured using a 1m long, 50mm diameter, clear acrylic clarity tube, graduated along its length in centimetres, and with a black magnetic disc in the tube. A direct reading on the tube indicated the degree of turbidity (Table 3). Persistent turbidity may result in distortions of macroinvertebrate assemblages and, where severe, on the fish population.

**Table 3.** Definitions of turbidity readings using direct readings from clarity tube (from SHMAK, 2002)

| Clarity tube readings | Turbidity |
|---|---|
| >90cm | Clear to bottom |
| 70-90cm | Slightly turbid |
| 55-69cm | Moderately turbid |
| 30-54cm | Very turbid |
| <35cm | Extremely turbid |

### Conductivity

The conductivity of the stream water was measured using a EUTECH Cybernetics TDScan 3, 0 1990 μS, automatically adjusted to 25°C, the measurements recorded as microsiemens/cm (μS/cm). The result measures of the ability of water to conduct an electrical current and is affected by the presence of inorganic dissolved solids and ions such as chloride, nitrate, phosphate, sodium, calcium and iron (Table 4). It may also be affected by water temperature, increasing with warmth, and by ions gleaned from the bedrock through which it flows, with clay soils giving high conductivity. Changes in conductivity may indicate pollution particularly with nitrate or phosphate. The presence of inorganic pollutants will alter the expected stream fauna assemblages.

**Table 4.** Definitions of conductivity readings using EUTECH Cybernetics TDScan3, 0 1990 (from SHMAK, 2002)

| Conductivity (μS/cm) | Interpretation of result |
|---|---|
| <50 | Very low concentrations of dissolved ions |
| 50 – 149 | Low concentrations of dissolved ions. |
| 150-249 | Slightly enriched waters. Thick slime and periphyton growth in summer |
| 250 - 399 | Moderately enriched water. Thick slime and periphyton on stable objects in stream in summer. |
| >400 | Enriched waters. Extensive green filamentous periphyton in summer. Catchment may be mudstone/siltstone. |

### pH

pH was assessed using Merck Neutralit strips (pH 5-10). These strips measure in 0.5 units, and after immersion for 10 minutes the colour is compared with the reference colours on the packet to give a reading. Clean stream water has a neutral pH of 7. Where the pH is low (<7) this indicates acidity as may arise from litter decomposition or acid soils (peat). Such acidity can compromise the sustainability of some assemblages of fish and/or aquatic invertebrates. Changes in pH from neutral to acid or alkaline (ph>7) may also indicate the presence of pollutants that have entered the water from animals or anthropogenically.

## Data analysis

## Multivariate analysis

Non-metric dimensional scaling (NMDS) ordination using PC-ORD (McCune & Mefford, 2002) was carried out to illustrate the relationships between the invertebrate communities. Environmental variables were then overlayed over ordination to reveal the relationships between invertebrate communities and the environment. Thirty environmental variables from the SEV database were used to isolate clusters of macroinvertebrates between streams and within the stream network.

## Metrics

### MCI, QMCI, EPT indices

The MCI, QMCI and EPT indices were calculated using the NIWA Excel spreadsheet. The MCI is the sum of the tolerance scores of the taxa collected divided by number of scoring taxa and this result multiplied by 20. (Winterbourn *et al*, 2000) (see Appendix 5); the QMCI is calculated from taxon scores using quantitative or percentage data (Boothroyd & Stark, 2000) and may be more sensitive than the MCI to organic pollution (Table 2); and the EPT index targets three populations of sensitive taxa as indicators of clean water ie. Ephemeroptera, Plecoptera and Trichoptera. A low EPT index implies pollution and poor water quality.

**Simpson's diversity index (1-D)**

The invertebrate community evenness index was calculated on a NIWA Excel programme using the formula

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where n = total number of organisms of a particular species,

N= total number of organisms of all species

Simpson's Diversity Index was calculated from 1-D where the greater the value, the greater the diversity, ie. the greater the species richness and evenness.

## Multimetrics

**Fish IBI**

The fish counts were entered into an EXCEL data sheet that also had information on site, altitude and distance from the sea, and the IBI score was calculated using IBI software (Joy, 2006). This uses 6 metrics specifically appropriate to New Zealand freshwater fish fauna where there is only one trophic level and no disease in the wild population. They were:

**Metric 1** (taxonomic richness): the number of native species. This metric excludes the alien species as they may influence the species richness in degraded habitats.

**Metric 2** (Habitat): the number of native benthic riffle species. This metric is an indicator of degradation in the riffle zones of streams

**Metric 3** (Habitat): the number of native benthic pool species

**Metric 4** (Habitat): the number of pelagic pool species. This metric excludes alien species which tend to be pelagic.

**Metric 5** (Intolerant species): the number of species intolerant to different environmental variables such as water quality and stream barriers.

**Metric 6** (Invasive species): the proportion of native to alien species in fish assemblages

## Results

### Stream ecological valuation (SEV)

The SEV results for the 4 key ecological functions at the 5 sites are shown in Table 5. The ecological values obtained showed that the network of streams contributing to the south branch of the Whareroa Stream had generally poor ecological environments. Site A had the poorest SEV of 0.44 reflecting a loss of ecological value of 56%, while sites B and C had losses of 44% and sites D and E of 32%.

**Table 5.** Ecological function scores for the Whareroa stream study reaches. (after Rowe *et al*, 2006)

| **Ecological functions** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| **Hydraulic** | | | | | |
| Natural flow regime (NFR) | 0.53 | 0.53 | 0.73 | 0.90 | 0.90 |
| Connectivity with flood plain (CFP) | 0.40 | 0.40 | 0.40 | 0.85 | 0.85 |
| Connectivity for migrations (CFM) | 0.51 | 0.51 | 0.51 | 0.51 | 0.51 |
| Connectivity to groundwater (CGW) | 0.70 | 0.70 | 1.00 | 1.00 | 1.00 |
| **Biogeochemical** | | | | | |
| Water temperature control (WTC) | 0.81 | 0.79 | 0.66 | 0.78 | 0.68 |
| Dissolved oxygen maintained (DOM) | 0.75 | 1.00 | 1.00 | 1.00 | 1.00 |
| Organic matter input (OMI) | 0.05 | 0.22 | 0.10 | 0.10 | 0.95 |
| In-stream particle retention (IPR) | 0.09 | 0.07 | 0.47 | 0.61 | 0.53 |
| Decontamination of pollutants (DOP) | 1.00 | 1.00 | 1.00 | 0.27 | 1.00 |
| Flood-plain particle retention (FPR) | 0.55 | 0.55 | 0.41 | 0.59 | 0.70 |
| **Habitat provision** | | | | | |
| Fish spawning habitat (FSH) | 0.55 | 0.75 | 0.59 | 0.88 | 0.43 |
| Habitat for aquatic fauna (HAF) | 0.31 | 0.55 | 0.54 | 0.50 | 0.66 |
| **Biodiversity** | | | | | |
| Fish fauna intact (FFI) | 0.67 | 0.60 | 0.57 | 0.80 | 0.57 |
| Invertebrate fauna intact (IFI) | 0.05 | 0.05 | 0.36 | 0.51 | 0.16 |
| Riparian vegetation intact (RVI) | 0.40 | 0.80 | 0.48 | 0.53 | 0.90 |
| | | | | | |
| **SEV (Mean)** | 0.44 | 0.57 | 0.56 | 0.67 | 0.68 |

Site A had a high DOP from an abundance of algae and in-stream macrophytes that were associated with increased nutrient and sediment run-off from farm streams. In-stream particle retention (IPR) was very poor at sites A and B resulting in very low IFI scores at both sites.

An apparent anomaly existed at Site E, which had the advantages of being in bush with a good leaf litter input (OMI) but had only moderate particle retention (IPR) and low FSH, FFI and IFI. In spite of the lack of riparian vegetation at site D, the high banks and stream habitat with riffles, pools and undercuts, were associated with greater biodiversity than any other site (Table 6).

**Table 6**. Summary of Functional scores for each reach (as percentages) and the final SEV score as per the ARC stream valuation protocol (after Rowe *et al*, 2006).

**Ecological values (%)**

| **Sites** / *Function* | A | B | C | D | E |
|---|---|---|---|---|---|
| Hydraulic | 53 | 53 | 66 | 83 | 81 |
| Biogeochemical | 54 | 60 | 54 | 55 | 81 |
| Habitat provision | 43 | 65 | 56 | 69 | 55 |
| Biodiversity | 37 | 48 | 47 | 61 | 54 |
| | | | | | |
| **SEV (Mean) %** | 44 | 57 | 56 | 67 | 68 |

These results indicated that there was serious degradation of ecological function present at all sites but worst downstream at site A (Table 6).

**Multivariate analysis**

Non-metric dimensional scaling ordination (NMDS) of the data showed clearly the relationships between invertebrate communities (Figure 8). The ordination of the macroinvertebrate communities had a stress for two dimensions of 22 for Axis 1, and 8 for Axis 2, indicative of the relatively small number of taxa able to be ordinated from the Whareroa stream network The ordination clearly showed that changes occurred in the macroinvertebrate assemblages, with time and season at sites A, B and E, whereas sites D and C had similar assemblages in both seasons. Also of note was the similarity in the macroinvertebrate communities at sites E and D, and another similar community at sites A and C.

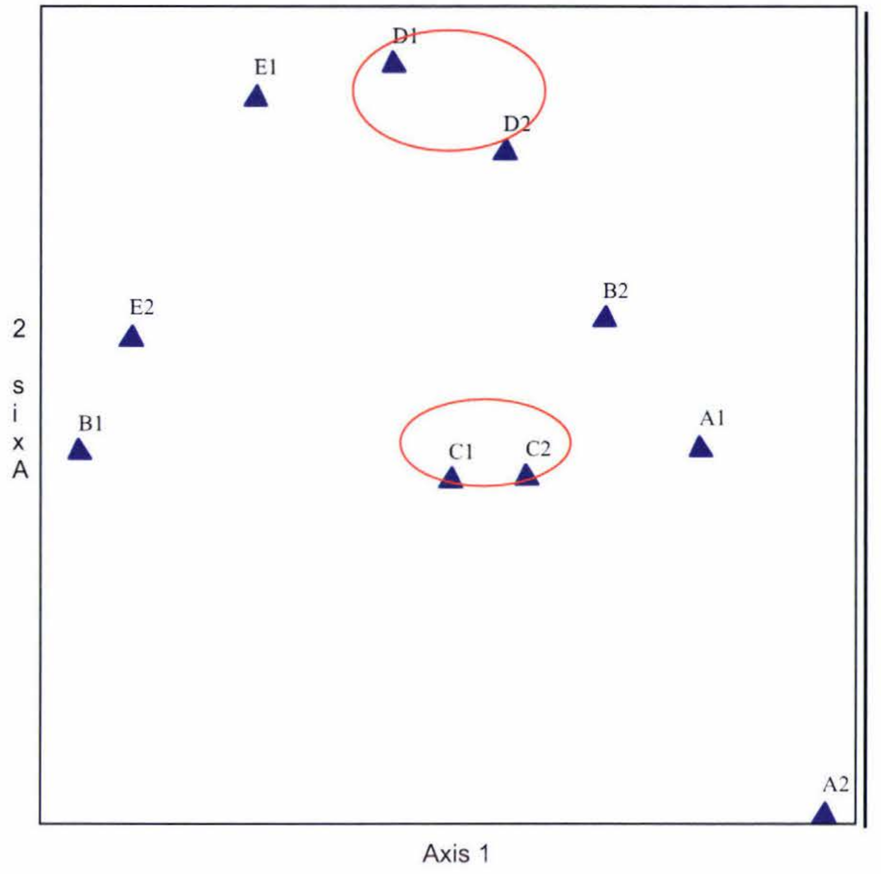



**Figure 8.** NMDS ordination of Axis 1 against Axis 2 for the 5 sites using macroinvertebrate communities for the two seasons. (A1 - E1 = November 2006; A2 - E2 = March 2007).

The correlation between the macroinvertebrates and the most important ecological functions over two seasons are demonstrated by the Figure 9 bi-plot graph. The communities at sites A and B, where there were significant flow rates (velocity), differed markedly from the communities at sites E and D. In-stream particle retention (ipr), connectivity with the floodplain (cfp), organic matter input (omi), aquatic habitat (haf), natural flow regime (nfr) and pools were higher at these sites. The changes in correlations with season were evident at sites A, E, and B.

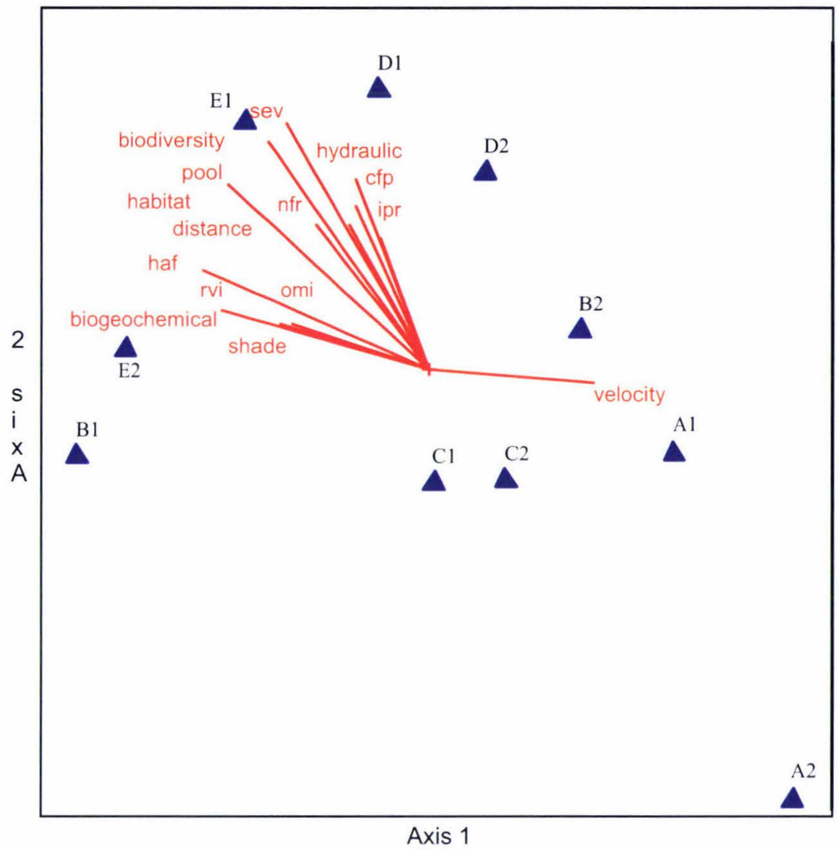



**Figure 9** A biplot graph showing the SEV factors that correlated with the macroinvertebrate assemblages over two seasons. (A1 - E1 = November 2006; A2 - E2 = March 2007)

The length of the red line on the bi-plot graph reflects the relative importance of the relationship. The prominent presence in the ordination of the SEV ecological functions ie. hydraulic, biogeochemical, habitat provision and biodiversity, (Table 1) correlated with their role in the development and sustainability of successful invertebrate communities at sites D and E.

Figure 10 illustrates the dominance of pollution-insensitive macroinvertebrates throughout the year at sites A, B and C ie. *Tanypodiae*, *Isopodae*, *Physa*, *Paracalliope* and *Hydrophilidae*. By contrast, sites E and D had an abundance of the pollution-sensitive mayfly, *Deleatidium,* and caddis fly, *Olinga feredayi,* in the late spring, this dominance persisting into autumn at site D.

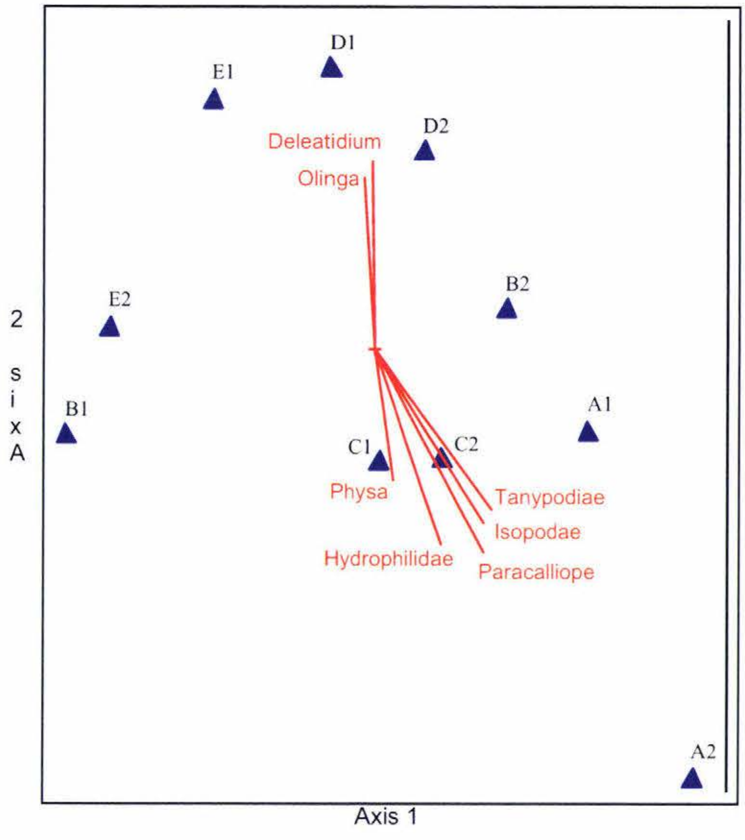



**Figure 10.** A biplot graph showing the NMS ordination of the invertebrate communities with individual species with correlation coefficients >0.5 overlaid as the biplot. (A1-E1 = November 2006; A2 -E2 = March 2007).

### Habitat quality and seasonal effects

The MCI and QMCI values as indicators of organic enrichment, showed that, using the criteria of Wright-Stow & Winterbourn (2003), no site had clean water (Table 7), though site D was the least polluted with QMCI values of >5.9 on both occasions and site E the most improved (Table 8). Site B showed the greatest improvement in both MCI and QMCI, possibly associated with the withdrawal of construction at Mackays Crossing. The MCI and QMCI values generally improved over the summer period with the greatest improvement being in the sites that had reasonable tree shade ie. sites B and E .

**Table 7.** MCI and QMCI as measures of water quality at the study sites. (after Wright-Stow & Winterbourn).

| **Site** | **Quality Nov 06** | **Quality Mar 07** |
|---|---|---|
| A | Severely degraded | Moderately degraded |
| B | Moderately degraded | Doubtful quality |
| C | Moderately degraded | Moderately degraded–doubtful quality |
| D | Doubtful quality- clean | Doubtful quality- clean |
| E | Moderately degraded | Doubtful quality |

**Table 8.** Comparison of MCI, QMCI and EPT scores in November 2006 and March 2007 at each site.

| Sites | Nov MCI | March MCI | | Nov QMCI | March QMCI | | Nov EPT score | March EPT score | |
|---|---|---|---|---|---|---|---|---|---|
| A | 81.33 | 88.91 | ↑ | 3.97 | 4.76 | ↑ | 0.029 | 0.011 | ↓ |
| B | 86.67 | 115.9 | ↑ | 4.11 | 5.18 | ↑ | 0.359 | 0.648 | ↑ |
| C | 99.05 | 102.98 | ↑ | 4.37 | 4.80 | ↑ | 0.167 | 0.172 | ↓ |
| D | 115 | 112.98 | ↓ | 6.46 | 7.38 | ↑ | 0.684 | 0.459 | ↓ |
| E | 95.71 | 108.57 | ↑ | 7.21 | 5.42 | ↓ | 0.887 | 0.529 | ↓ |

**Seasonal distribution of macroinvertebrate assemblages**

As the MCI and QMCI rely on the presence or absence of sensitive taxa, samples of the macroinvertebrates were collected from each reach in November 2006, and March 2007, to determine any seasonal difference in the aquatic invertebrate communities with seasonal changes (Table 8). The distribution of the aquatic macroinvertebrates changed with the season resulting in MCI scores being increased or unchanged (site D) over the summer to autumn, and QMCI values increased except at site E.

The macroinvertebrate population over the network of streams was small. Of the 33 taxa identified in the stream network, there was only a moderate representation of Ephemeroptera (4) and Trichoptera (8) taxa. The greatest numbers were at site B - Ephemeroptera (1) and Trichoptera (5), and site D - Ephemeroptera (2) and Trichoptera (7), but the total numbers of individuals was small. This was also the pattern with the dipterans *Austrosimulium* and *Chironomus*, and the coleopteran Elmidae. The few Plecopterans found were *Stenoperla* (1) and *Zelandoperla* (1) at site D and *Austroperla* (1) at site B, all in the late spring. The elevation of the site (165m a.s.l.) may have been one factor at site C for a reduced autumn distribution (Table 9).

**Table 9.** Distribution of macroinvertebrate taxa according to season and elevation.

| Site | Elevation (m) a.s.l. | Number of taxa Nov 2006. | Number of taxa March 2007 |
|---|---|---|---|
| A | 16 | 15 | 9 |
| B | 19 | 15 | 12 |
| C | 165 | 21 | 12 |
| D | 154 | 16 | 18 |
| E | 61 | 14 | 14 |

EPT scores were lower in the autumn except at site B where an increase in the March EPT score was associated with an increase in *Pycnocentria* numbers (Table 10). The total number of EPT taxa was small in both seasonal surveys (Figures 11 & 12). Ephemeropteran species, *Coloburiscus* and *Zephlebia,* were present in November but not in March, but *Deleatidium* was present in both surveys (Table 10). The Trichopteran species were more evenly distributed with *Olinga* and *Hydrobiosis* occurring in both November and March and *Aoteapsyche*, *Helicopsyche*, *Hydrobiosella* and *Pycnocentria* present in the March samples. The presence of the Trichopteran, *Psilochorema,* and the crane fly, *Eriopterini* at site C, implies a degree of pollution tolerance by these taxa as they prefer clean water but were found in a 'moderately degraded' habitat (Table 7). The dispersal of the macroinvertebrates and the relative lack of Ephemeroptera and Plecoptera, suggests that the habitats were generally unfavourable for them.

The distribution of Diptera also changed with fewer *Austrosimulium* and *Chironomus* found in the March samples. Though there were noticeable increases in the numbers of *Potamopyrgus* at site C and *Paracalliope* at site A in March (figures 11 & 12), this was not a seasonal increase but associated within-stream conditions of pollution and excess macrophyte growth.

**Table 10.** Metrics calculated for invertebrate communities collected at each site in November 2006 and March 2007.

| **NOVEMBER 2006** | A | B | C | D | E |
|---|---|---|---|---|---|
| Number of taxa | 15 | 15 | 21 | 16 | 14 |
| Number of individuals | 172 | 117 | 791 | 548 | 372 |
| MCI | 81.33 | 86.67 | 99.05 | 115 | 95.71 |
| QMCI | 3.97 | 4.11 | 1.37 | 6.46 | 7.21 |
| EPT | 0.029 | 0.359 | 0.167 | 0.684 | 0.887 |
| Simpson's Index | 0.655 | 0.187 | 0.178 | 0.411 | 0.558 |

| **MARCH 2007** | A | B | C | D | E |
|---|---|---|---|---|---|
| Number of taxa | 9 | 12 | 12 | 18 | 14 |
| Number of individuals | 542 | 572 | 639 | 1162 | 153 |
| MCI | 88.91 | 115.9 | 102.98 | 112.98 | 108.57 |
| QMCI | 4.765 | 5.183 | 4.802 | 7.376 | 5.418 |
| EPT | 0.011 | 0.648 | 0.172 | 0.459 | 0.529 |
| Simpson's Index | 0.021 | 0.277 | 0.381 | 0.317 | 0.184 |

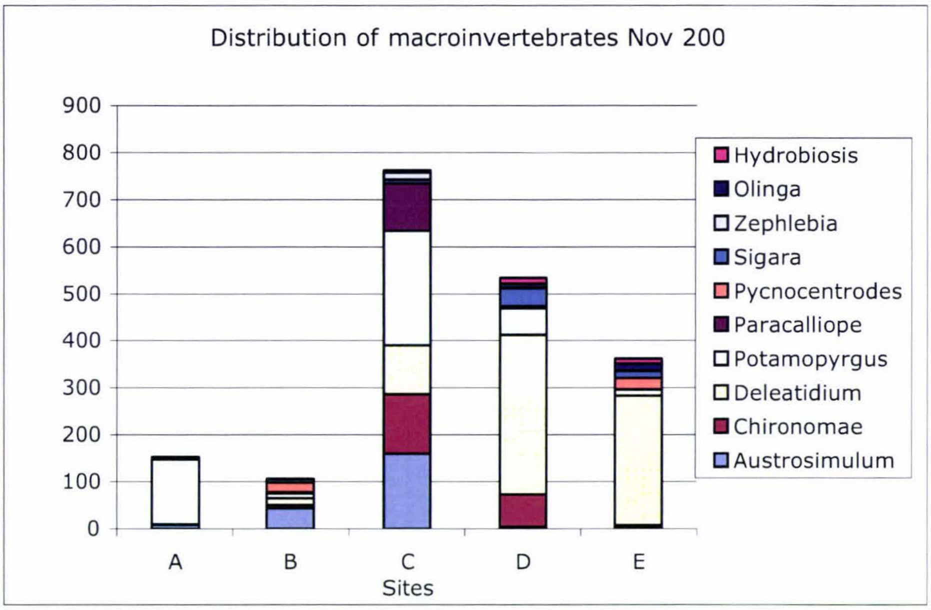



**Figure 11.** The spring (November 2006) distribution of top 10 macroinvertebrates, with dominance of *Potamopyrgus* at sites A and C, and of *Deleatidium* at sites D and E.

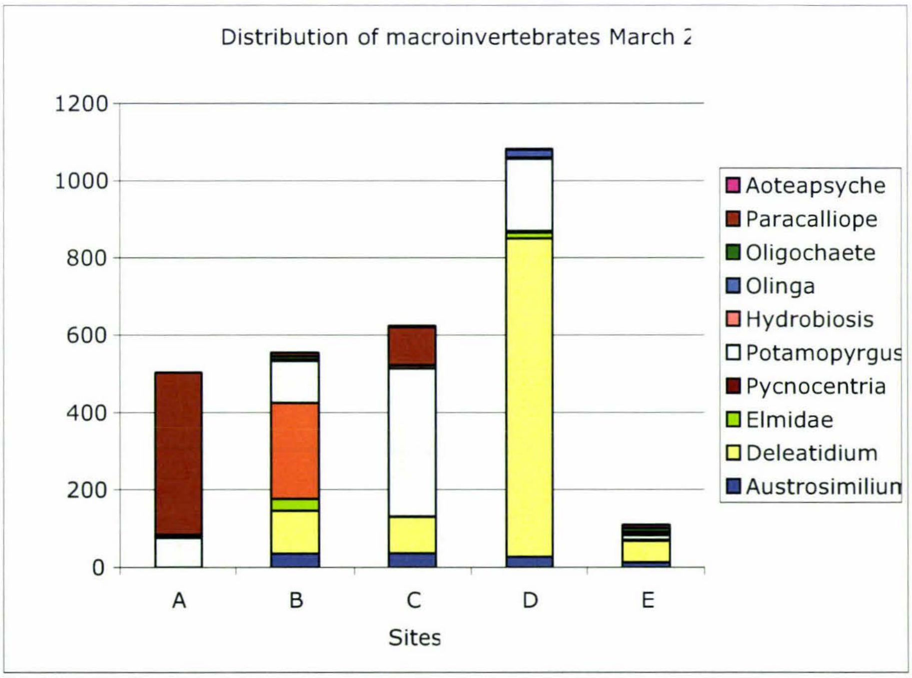



**Figure 12.** The late summer (March 2007) distribution of macroinvertebrates with dominance of *Paracalliope* at site A, *Pycnocentria* at site B, *Potamopyrgus* at site C, and *Hydrobiosis* at site D.

**Simpson's diversity index**

Simpson's Diversity Index (1-D) calculation provided information on species diversity where the higher the value of the index, the greater the diversity (Figure 13). The index represents the probability that two individuals randomly selected from a sample will belong to different species. The summary chart of the Whareroa sites (Table 11) indicated that the evenness (diversity) of the macroinvertebrates within the stream network was greater in the March than in the November.

**Table 11.** Data for Simpson's Diversity Index (1-D).

| **Sites November** | **1-D** | **Sites March** | **1-D** | |
|---|---|---|---|---|
| A1 | 0.345 | A2 | 0.979 | ↑ |
| B1 | 0.813 | B2 | 0.723 | ~ |
| C1 | 0.822 | C2 | 0.619 | ↓ |
| D1 | 0.589 | D2 | 0.683 | ~ |
| E1 | 0.422 | E2 | 0.816 | ↑ |
| **Average** | **0.598** | | **0.724** | |

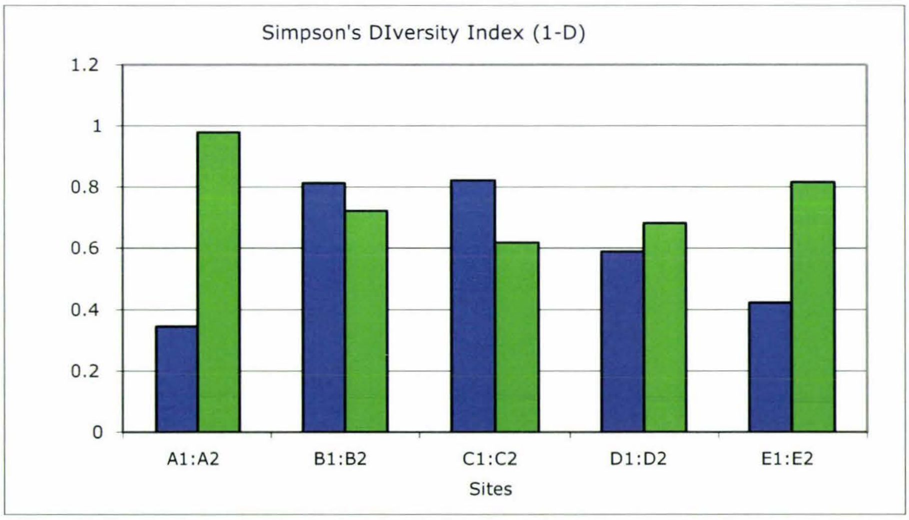



**Figure 13.** Whareroa Stream network community evenness - Simpson's Diversity Index (1-D) – indicating a shift with the seasons increased diversity upstream in autumn. (A1-E1 = November 2006; A2-E2 = March 2007)

**Fish Index of Biologic Integrity (IBI)**

The Index of Biotic Integrity for Fish (Table 13) showed that site D had the most consistent distribution of fish, coinciding with the highest SEV and water quality (Tables 6 & 7). The other sites were all rated as 'poor – fair', closely reflecting their other parameters including poor riparian integrity at sites A and C (Table 5) and nutrient excesses at site A (Table 6). Though Site E had excellent riparian cover and leaf litter, it had a poor resident population of galaxiids (Table 5), but inanga (*G. maculatus*) were seen 25m downstream. Site D had a Fish IBI rating of 'very good' for both seasons (Table 13).

Shrimps (*Paratya sp.*) were not present at sites upstream of the Mackays Crossing culvert, but koura (*Paranephrops*) were found at site B (below Mackays Crossing) and sites C and D (above Mackays Crossing) (Table 12).

**Table 12.** Seasonal distribution of fish and decapods at study sites. (A1 – E1 = November 2006; A2 – E2 = March 2007)

| | | Sites | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Common name | A 1 | A 2 | B 1 | B 2 | C 1 | C 2 | D 1 | D 2 | E 1 | E 2 |
| *Galaxias maculatus* | Inanga | 20 | 4 | 12 | 6 | | | | | | |
| *Galaxias fasciatus* | Banded kokopu | 1 | | | 1 | | | 7 | 2 | 1 | 1 |
| *Galaxias brevipinnis* | Koaro | | | | | | | 3 | 1 | | |
| *Gobiomorphus huttoni* | Redfin bully | 1 | | 10 | 8 | 4 | 3 | | 12 | 14 | 12 |
| *Anguilla australis* | Shortfin eel | 5 | | | 3 | | | | | | |
| *Anguilla dieffenbachii* | Longfin eel | 13 | 4 | 15 | 20 | 6 | | 2 | 2 | 10 | 3 |
| *Anguilla spp* | Elvers | | | | 30 | | | | | | |
| *Retropinna retropinna* | Common smelt | 1 | | 1 | | | | | | | |
| *Paranephrops* | Koura | | | | 1 | 3 | 1 | 1 | | | |
| *Paratya sp* | Shrimps | | | 10 | | | | | | | |

**Table 13.** Index of fish IBI (after Joy, 2006).
(A1-E1 samples January 2007; A2-E2 samples May 2007)

| Site | IBI score | Rating |
|---|---|---|
| A1 | 40 | Good |
| A2 | 30 | Fair |
| B1 | 36 | Fair |
| B2 | 26 | Poor |
| C1 | 34 | Fair |
| C2 | 26 | Poor |
| D1 | 48 | Very Good |
| D2 | 50 | Very Good |
| E1 | 34 | Fair |
| E2 | 34 | Fair |

Rating scores determined using 6 metrics:

20 – 29 = Poor

30 – 39 = Fair

40 – 45 = Good

>45 = Very Good

**Figure 14.** Longfin eels (*Anguilla dieffenbachia*) at site A.

**Figure 15.** Koura (*Paranephrops*) from site B

**Figure 16.** Koaro (*Galaxias brevipinnis)* from site D

**Figure 17**. Redfin bully (*Gobiomorphus huttoni)* from site B

**Temperature variation**

The temperature loggers were retrieved from all the sites after 185 days (26/11/07 – 31/05/07). Unfortunately, the logger at site C had leaked and there was no data for that site. This was an unexpected situation as it appeared to be intact on regular visual inspection. The data from the other four loggers showed high maximum temperatures at all sites suggesting that either periods of low flow may have occurred when they were not completely covered or the water in the upstream catchments was subject to high daily temperatures with the lack of riparian protection (Table 14). All the farm streams were shallow and heated quickly when exposed to solar radiation.

Minimum temperatures were higher than expected at >9.82C. The lowest daily temperatures typically occurred at 500hrs each day and the highest between 0500-1700hrs (Figures 18 & 19).

**Table 14.** Results of 185 days of temperature recordings at all sites (26/11/06 – 31/05/07). Site C logger did not record due to water leakage.

| Site | Maximum T°C | Minimum T°C | Average T°C | STD DEV | Amplitude T°C |
|---|---|---|---|---|---|
| A | 25.56 | 10.6 | 15.79 | 2.459 | 3.6 (14.15-038) |
| B | 23.24 | 9.82 | 15.20 | 2.791 | 4.45 (10.73-0.77) |
| C | | | | | |
| D | 26.34 | 9.82 | 14.65 | 2.271 | 3.18 (11.11-0.38) |
| E | 21.33 | 9.82 | 14.56 | 2.164 | 2.50 (6.94-0.38) |

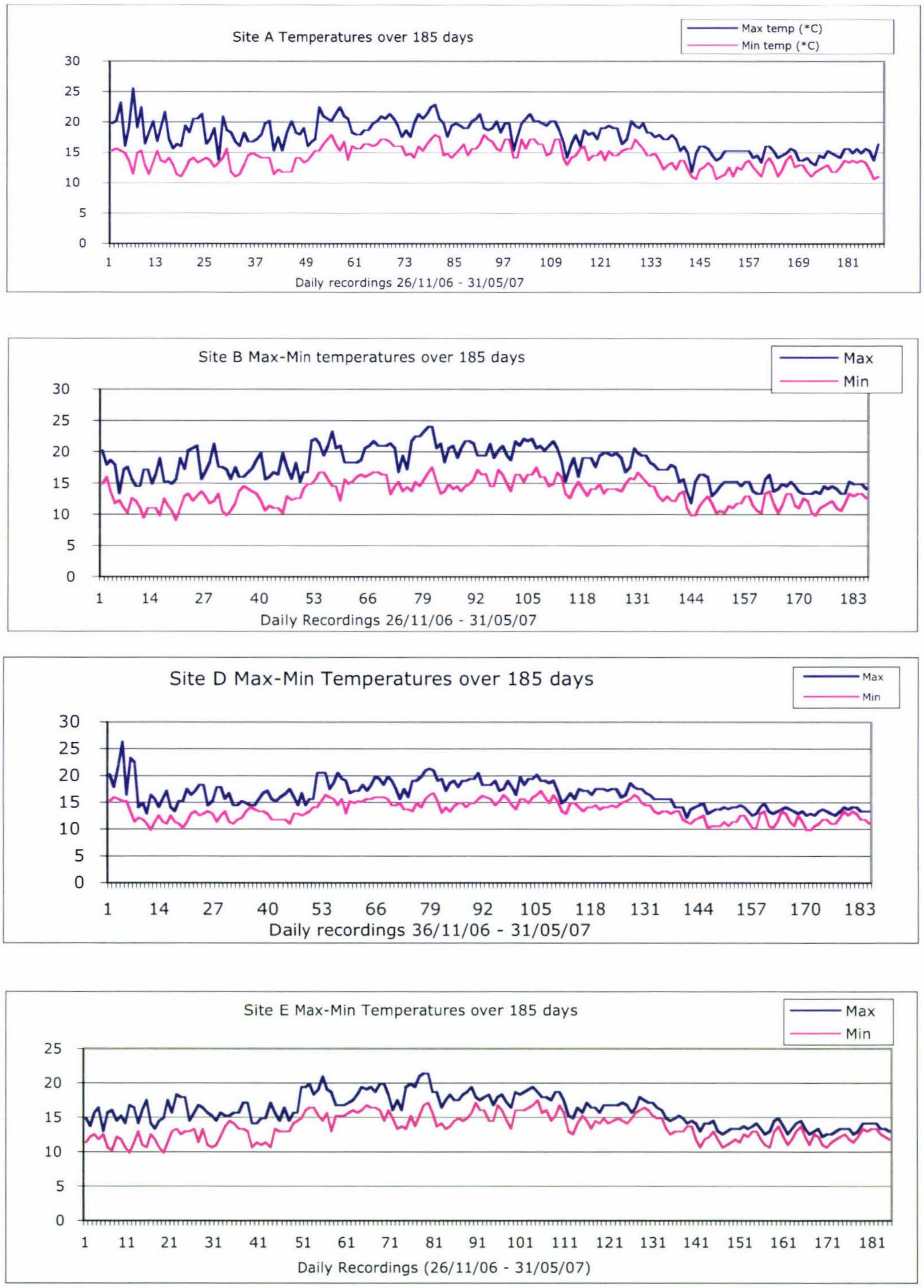



**Figure 18.** Maximum – Minimum Temperatures at sites A, B, D, and E. over 185 days from 26/11/06 – 31/05/07.

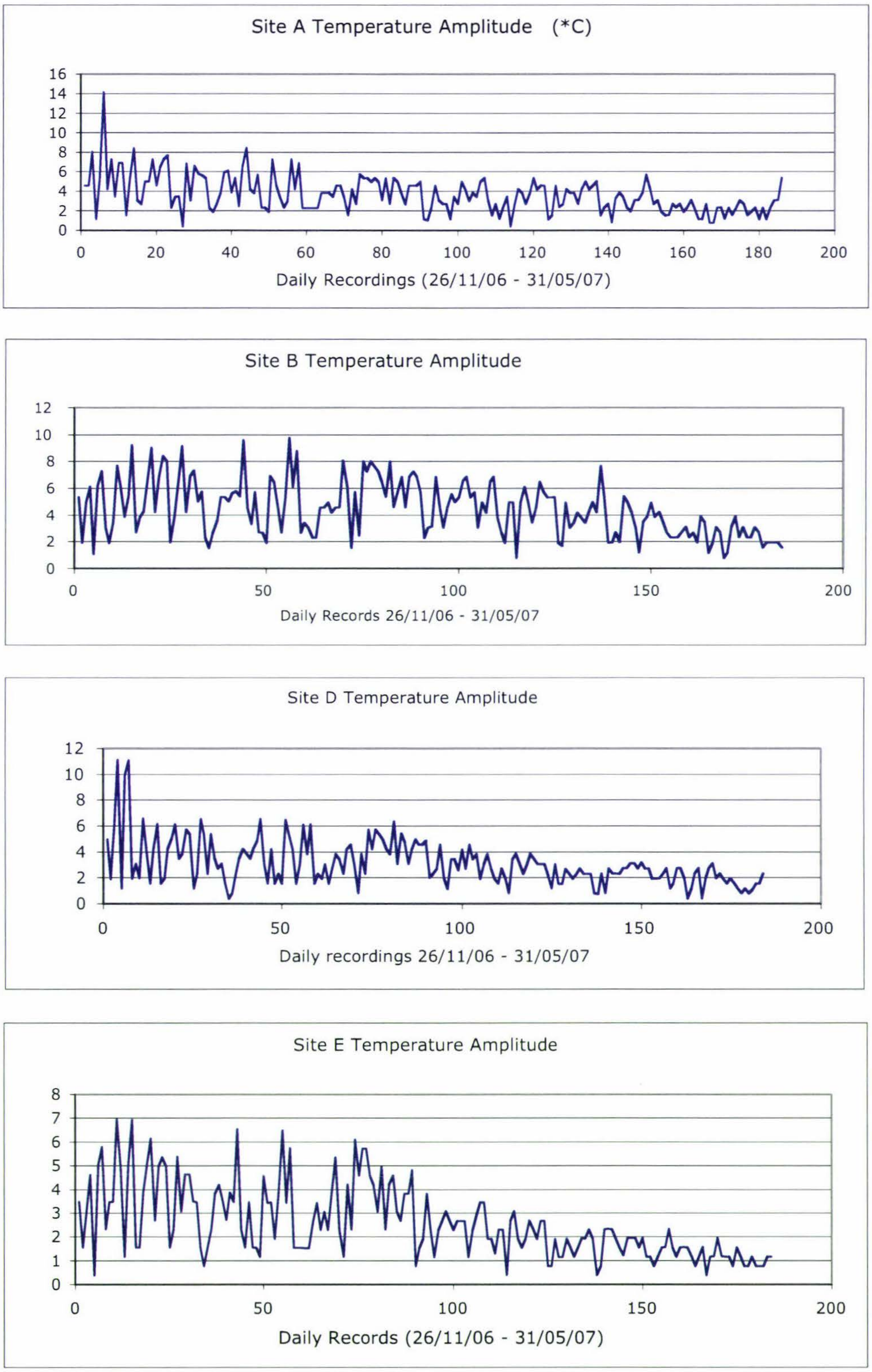



**Figure 19.** Amplitude of temperature variations over 185 days from 26/11/06 to 31/05/07.

### Turbidity

The water clarity as measured by the clarity tube showed only minor variations between sites and all were within the range of "slightly turbid" (Table 15). The apparent clarity of the water at Site C in spite of bank damage by cattle was associated with no farm animal movement near the site on the week before testing. However, a population of recently dead, but intact, land slugs in the stream bore testimony to recent bank destruction.

**Table 15.** Results of turbidity survey using a clarity tube.

| SITE | Distance seen |
|---|---|
| Site A | 70cm |
| Site B | 75cm |
| Site C | 75cm |
| Site D | 80cm |
| Site E | 70cm |

Site D was the clearest stream, with little stock movement nearby, a rocky base, riffles and pools and gorse providing some riparian functions.

### Conductivity

Measurements of conductivity taken at each study site showed increased conductivity as the network streams became larger and absorbed water from tributaries draining farmlands. Sites A and B measurements indicated slight to moderate enrichment of the water (Table 16).

**Table 16.** Results of conductivity and pH measurements:

| Site | Conductivity (µS/cm) | PH |
|---|---|---|
| A | 230 | 7.0 - 7.5 |
| B | 210 | 7.5 |
| C | 190 | 7.5 |
| D | 190 | 7.5 |
| E | 190 | 7.5 |

### pH

The pH of the stream water was measured at each site and found to be neutral at all sites (pH = 7-7.5). The incremental change on the tape was 0.5 units and therefore relatively insensitive to small differences (Table 16). The readings were undertaken in the late mornings. The peat soils did not cause any acidity.

## Discussion

### Impacts on streams

This study confirmed the hypothesis that the land use changes at Whareroa Farm and Queen Elizabeth Park over the last century have affected the ecological health of the network streams of the south branch of the Whareroa Stream. Previous studies have highlighted that the damage that is inflicted by land use change to agriculture (Harding & Winterbourn, 1995; Gessner & Chauvet, 2002); Thompson & Townsend, 2004; Macdonald, 2006**)**, and in particular the loss of the riparian function in a catchment, is a direct cause of loss of ecological health, stream dysfunction and degradation of stream structure throughout an entire stream network. The south branch of the Whareroa Stream exhibited the results of such changes throughout its catchment. The challenges to be met in restoring its ecological integrity have been highlighted by the deficits identified in the SEV protocol.

**Ecosystem Function**

The ARC Stream Ecological Valuation (SEV) assessment provided evidence of ecological degradation in all functions (Table 6). Individual ecological functions were widely varied across the sites when compared with the reference streams in the SEV protocol. Site A had an loss in ecological value of 56%, while sites B and C showed losses of 44% and sites D and E of 32%. The reasons behind the poor ecological functions over the stream network were defined by the 16 variables in the four ecological functional categories of the SEV and illustrated by multivatriate analysis (NMDS ordination scaling). Of particular note were the poor results across all sites in organic matter input, in-stream particle retention, flood-plain particle retention, fish spawning and aquatic fauna habitats, fish and invertebrate fauna assemblages and riparian vegetation.

The severity of the changes to the lower reaches of the stream network was seen in all the ecological functions. Site A showed the poorest results in all functions (Table 5). Hydraulic function assessment showed a reduction in both the natural flow regime and the connectivity with the floodplain. Channelisation and modification of the streambed, compaction of the land following drainage of the peat land, increased nutrient from farm run-off, and reduced connectivity with groundwater, were the main factors affecting the reach. The impact of these changes on the migration of taxa did not appear to be any greater than at other sites, reinforcing its role as a transit site to upstream spawning areas and not a primary habitat.

**SEV analysis**

Although most ecological functions in the upper reaches were within the acceptable ranges established by the SEV prorocol, there was a marked loss of hydraulic function at site C where slumping of the land and cattle-induced damage to the stream banks demonstrated the effects of past and present cattle farming. The destruction of banks on floodplains will increase sediment in streams and prevent galaxiid spawning. There was no evidence of galaxiids at site C but redfin bullies (*Gobiomorphus huttoni*), elvers (*Anguilla spp*) and koura (*Paranephrops*) were found.

The SEV protocol scored sites D and E with higher ecological values than all other sites and this was illustrated by ordination (Figure 9). The high biogeochemical function score (shading, organic matter input, wood debris and particle retention) for site E on the Ramaroa Stream (a tributary of the Whareroa Stream) was associated with a riparian zone of >20m on both banks. Site D had a high right bank and tall gorse on the left bank providing some shade. The very low OMI scores at sites A, C, and D were indications of the lack of a leaf resource at those sites, and at site B was a reflection that the leaf fall was not entering the stream as the deciduous trees were too distant from the water edge.

The loss of the riparian zone at most sites was a consequence of the pastoral farming practices where a lack of appreciation of the importance of these zones had led to the degradation of the stream banks, loss of sediment into the stream and loss of vegetation that would have provided protection to the banks and cover for the water. The lack of leaf or wood for those streams and modifications of the streambeds prevented any leaf retention. These functions are basic to primary production in a stream, and thence to the assemblages of macro-invertebrates and fish. Lack of wood also affects secondary production with the loss of suitable habitats for galaxiid and bully spawning.

Eikaas *et al* (2005) reported on the relationship between position and proportion of forest in catchments and the presence of diadromous fish. They concluded that where forest was present at the lower reaches, the populations of koaro were greatest, but if it was mainly in the upper catchment only, then there was little effect on the presence of fish.

The lack of koaro in the forested section of the Whareroa Stream at site E was likely to have been associated with the limited forested area (<100m length) providing insufficient cooling of stream water (Table 14), inadequate lighting through the canopy and limited wood input to the stream. Though site A was unshaded, the excess in-stream vegetation and depth of water were helpful in assisting with water temperature control there. The best habitat for fish was at site D where banded kokopu, koaro, longfin eels and redfin bullies were all present. The site had pools, riffles, small runs, undercuts and some shade from the high banks and tall gorse ensuring some stream protection. NIWA (2006) identified the ideal habitat for banded kokopu as a small, low gradient, first order, perennial stream with forest cover. The only site with most of these credentials was site E but only one small, banded kokopu was found. Its upstream components of open spaces and no headwater bush are likely to have had an effect on the fish distribution.

**Structural components**

Many studies have related the presence or absence of New Zealand diadromous fish to altitude and distance-from-the-sea, but other habitat functions such as stream order (first or second order), gradient (low, medium or high), flow (perennial or ephemeral) and forest cover, may be as or more important in determining their presence (McDowall, 1998; NIWA, 2006; Joy & Death, 2004). Elevation was a significant factor in the presence or absence of taxa only at site D (Figure 9). There was a small increase in total macroinvertebrate taxa numbers in November at site C, the highest site, but not of fish.

Increased summer water temperatures, increased algal levels and possibly increased nutrient levels in the stream from cattle at site D, were associated with the presence of the Trichopteran, *Helicopsyche,* during March, 2007. Algae are a major food source for *Helicopsyche* (Harding & Winterbourn, 1995). Studies in South Island pastoral streams have found that other Trichopterans also use algae as an important food source, including *Olinga feredayi*, *Pycnocentria spp.* and *Aoteapsyche spp.*, all of which were found at the study sites. Elmidae were found at site D in March 2007, and are known to prefer warm temperatures up to 24°C (Quinn *et al*, 1994).

However, compromised stream health was evident in March 2007 with macroinvertebrate communities showing increased numbers of pollution-insensitive invertebrates including *Paracalliope, Tanypodiae* and *Isopodae* at site A where there was farm stream run-off (Figure 10) and *Hydrophilidae* at site C which was frequented by cattle. The mollusc, *Potamopyrgus sp.,* increased across all sites with the increased growth of macrophytes. .

*Deleatidium* was the dominant species in all the farm streams throughout the survey, a feature also found countrywide in pasture streams and braided rivers (Death, 1996). Of the 10 most abundant taxa over the stream network seasonally, 6 taxa occurred in both spring and autumn but with different community composition (Figures 11 & 12). This was in keeping with the findings of Fowler & Death (2000) who found in their studies of rivers of the Hawkes Bay that while the taxa were the same, the composition of the macroinvertebrate communities varied with the season. The influence of low flows and increased water temperatures over the summer months may have been relevant in the Whareroa tributaries.

**Indices**

The baseline biotic indices for stream health included the relative abundance and /or dominance of taxa, EPT pollution sensitivity and Simpson's macro-invertebrate species evenness (richness). They showed a stream network with mild to moderate degradation in water quality. The MCI and QMCI at site D were better and more consistent over time than other sites (Table 7). The indices for sites A and C were of concern with moderate to severe degradation/pollution occurring. This finding was in line with the SEV of these sites.

The Fish IBI reflected the MCI and QMCI, with a 'very good' result at site D which had clean water, riffles, pools, short runs, and undercut banks, but only 'fair' to 'poor' results for other sites (Table 13). These results were consistent over both seasons. Seasonal samples were taken to gauge what effects seasonal changes in macroinvertebrate assemblages had on fish communities. However, the seasonal geographic distribution of the fish was largely unchanged (Table 12) but the numbers of inanga at site B had declined in May, as had the numbers of longfin eels at sites C, D and E. The number of redfin bullies had increased at sites C, D and E in May.

The upstream penetration of diadromous fish was evaluated in Taranaki by Joy *et al.* (2000). They found that inanga and smelt had limited upstream penetration. This was reflected in this study, where inanga were seen 6km inland and up to 60-70m above sea level near site E, and smelt only at site B that was 3km inland and19m above sea level. The gradient of the streams above Mackays Crossing may have been too great for smelt penetration. As with the Taranaki findings, the presence of longfin eels and elvers at all study sites is a reflection of their ability to tolerate some pollution and to populate streams at moderate altitude (site C 165m) and considerable distances from the sea (site D >6.2km).

New Zealand fish are largely diadromous moving within stream networks a well as between the sea and freshwater. As the area sampled was limited in size, there were only small numbers of fish collected, apart from longfin eels, and thus any indication of seasonal effects on the diadromous fish populations was uncertain. Longfin eels were the most prevalent at lower altitudes (<61m) and redfin bully at the highest altitude (>165m). Concern that the culvert at Mackays Crossing was a barrier to migration was not borne out. However, the cattle contamination of site C may have been significant in galaxiid habitat selection for that stream. The influence that a recent rough earth dam fashioned at the lower end of site D may have had on the transit of migratory fish during the summer was unclear from the second sample figures.

The measurements of water turbidity, conductivity and pH reflected the biotic indices with respect to stream health with poorest results at the lowest reaches. The best results were at site D, where, though riparian vegetation was sparse above and below the reach, the gorse at the study site had effective filtering activity. Water temperatures were warmer, both day and night, over the last 3 months of recording (March-May, 2007) than historically found in NIWA data. The lack of shading for all the catchments and lower flows during the late summer period ensured increased macrophyte growth and an upsurge of molluscs and crustacea (amphipods) in the upper reaches.

**Functional components**

The reduction in stream primary production through lack of leaf litter at most sites may have compromised the habitat for macroinvertebrates and fish throughout the network. This was quantified in the SEV functions of habitat provision and biodiversity that scored poorly at all sites. There was inadequate riparian wood debris at all sites for bullies and galaxiid spawning and inadequate leaf litter at most sites for aquatic invertebrate activity. The composition of leaf litter is a major factor in any macroinvertebrate assemblage. Collector-browsers, such as *Olinga feredayi*, favour rapidly decomposing leaves, eg. mahoe (*M. ramiflorus*), while leaves with 'toughness' are processed by microbial activity (Quinn *et al.*, 2000).

Gessner and Chauvet (2002) showed that in pastoral streams the rates of organic matter decomposition were increased. The effect of a reduction in the primary production of oxygen on the composition of the macroinvertebrates assemblage is to favour less sensitive taxa such as molluscs and oligochaetes. The collapse and decomposition of macrophytes and algae at site A in the late summer was associated with a marked reduction in macroinvertebrate taxa from 15 to 9 and loss of the EPT and dipteran components of the assemblage (Table 10).

**Summary**

In summary, the Whareroa Stream's ecological valuation results confirmed the degradation of the stream network associated with over a century of agricultural land-use. No site studied had a mean SEV score greater than 70% and site A showed a loss of ecological value of 46%. The water quality was poor to moderate as judged by the MCI and QMCI values. Turbidity was slightly raised at the lower reaches and macrophyte growth was excessive there also. The total numbers of taxa were small and the EPT diversity generally poor. The Fish IBI indicated that only site D had an adequate habitat for galaxiids and bullies. The riparian zones had little or no vegetation apart from grasses except at site E.

However, the variety of fish fauna found at site D giving a 'very good' IBI, suggests that successful spawning could occur with increased stream protection and appropriate in-stream nutrients. The restoration of the stream habitat for an increase in numbers and diversity of fauna will depend on decisions around the riparian potential in the presence of on-going farming. The stream banks are damaged in many places particularly near site C (Figure 27).

The concern regarding a barrier to fish passage through the Mackays Crossing culvert was not dispelled though inanga and other galaxiids were found in streams above the culvert. These may have been part of a pre-culvert population. Further studies will be required to clarify this issue. The challenges for the upper catchment will be a compromise between the various claims to its use ie. multi-disciplinary approach to farming, recreation and stream modifications (Palmer *et al.*, 2003).

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# Chapter 3
# Whareroa Streams – a riparian evaluation

Riparian zones are three-dimensional zones of vegetation that provide for the ecological health of streams. They have a critical interface between land and water ensuring that any untoward effects from land use or abuse are mitigated before aquatic ecosystems are affected. Changes in land use from forestry to pasture or urban development with consequent loss of riparian zones, are an increasing issue in many parts of the country (Quinn, 2003).

Many New Zealand streams have particular characteristics associated with the young tectonically active geology of the country. They arise in steep, often deforested, hill country, are usually rain fed, and drop rapidly in height to the lowlands where there are extensive un-shaded lengths in the lower reaches (Thompson & Townsend, 2000).
The implications for stream function and structure of the loss of riparian vegetation becomes clear when assessment of the ecological integrity of the streams and rivers is undertaken (Quinn *et al.*, 1997).

Riparian zones function in varying ways spatially along the length of a waterway (Quinn, 2003). Their natural role is to enhance stream habitat and water quality by shading, filtering nutrient loads from the surrounding land, and providing habitats for macro-invertebrates and fish. Loss of these functions may lead to both the loss of fauna, and changes to the composition of the aquatic communities (Quinn *et al.*, 2000; Townsend *et al.*, 2003; Allan, 2004).

The composition of the riparian protection, whether native, exotic or a mix, appears to be less important than the presence of protection (Quinn & Scarsbrook, 2001). A 55% reduction in annual water yields to water channels in some New Zealand streams has been found to have occurred when there are forested buffer zones of >25m (Smith, 1992; Broadmeadow & Nisbet, 2004) and a reduction in nutrient loads has been found when there is riparian protection of headwaters (Parkyn *et al.*, 2001). In a review of Otago streams, Townsend *et al* (2003) found that the proximity of riparian protection to riffles was a significant factor in determining the composition of aquatic invertebrate communities. Increased wood recruitment occurs from trees 20-30m high, overhanging trees, grasses and shrubs, providing terrestrial insect food for fish in small streams. Collier and Smith (1998) found that the main activity for trichopteran macroinvertebrates in forested riparian zones was within 30m of the stream edge.

**Connectivity**

Longitudinal, lateral and vertical connectivity of stream environments are now being recognised as major components in stream assessment and therefore rehabilitation (Boulton, 2007; Lake *et al*, 2007; Jansson *et al*, 2007; Hughes, 2007). Longitudinal connectivity of streams and their surrounds commences in the catchment and follows through the valley segment to the lower reaches. Natural or artificial barriers, or any disconnections in the functional ecosystems of the streams may compromise it. The ability of an ecosystem to overcome any barriers has provided a huge problem for rehabilitation as the simple methods of removing them may in turn destroy ecosystems at a lower reach with sediment and debris escape (Jansson *et al*, 2007).

Some of the functional consequences of interference with longitudinal connectivity include increased turbidity, acidity and nutrient levels in a stream (Rutherfurd *et al*, 2001). The reduction of light in turbid water will reduce the rate of photosynthesis and hence the growth of benthic algae (Davies-Colley & Quinn, 1998). The direct effect on macroinvertebrates is small unless their food source is affected but fish can become stressed developing reduced feeding efficiency and lowered growth rates.

The acidification of streams may occur naturally where they pass through acidic rock or soils, but where it is the result of pollution (natural volcanic or anthropogenic) aquatic fauna will be markedly reduced. Alkalinisation of streams may occur as a result of exuberant macrophyte and periphyton growth from nutrient input, and result in a reduction of aquatic fauna.

Lateral connectivity between the stream and its banks and vegetation ensures stream bank stability in all but extreme conditions of flow. Banks are strengthened by root networks. Groundcover up to 1.0m high has been shown to be very effective in providing protection against soil erosion by bank reinforcement to 0.3m depth (Rutherfurd *et al*, 1999; Phillips & Marden, 2003). Roots also buttress the toe of a bank and reduce slumping. The depth of the roots relative to the height of the stream banks, bank angles, the effect of the sinuosity of the stream in reducing flow rates, erosion occurring during high flows, and the presence of debris and boulders have been found to be key factors in bank stabilisation (Quinn, 2003).

The most effective stabilisation occurs where the depth of root penetration is greater than bank height. Understorey trees up 5m usually have roots to 1m deep and laterally to the drip line. Taller trees typically have root networks to the drip line laterally and not more than 2m deep. Watson *et al.* (1999) found that mature kanuka ( *Kunzea ericoides*) of 6-32 years old had maximum root depths of 1.3 – 1.6m whereas *Pinus radiata* 8 - 25 years old had maximum root depths of 3m. Where bank height alters and/or there are gaps in the riparian cover, the bank is vulnerable to erosion.

Marden *et al.* (2005), studying the effectiveness of 12 indigenous woody species growing on unstable hill slopes and stream banks in New Zealand, noted that the ability of the species studied to stabilise ground and stream banks was limited by shallow rooting systems (~31cm). Although the root biomass increased 23% over 5 years, this was an effective method of bank stabilisation only where plant succession was in conjunction with removal of animal grazing and on $1^0$ and $2^0$ streams. It was not effective for large waterways.

Lateral connectivity between stream and bank is important for the entire length of the stream from the catchment. Connectivity into the floodplain is required for aquatic invertebrate reproduction eg. amphibite stoneflies (Stanford *et al*, 1994), and for fish spawning eg. koaro (*Galaxias brevipinnis*) and inanga (*G. maculatus*) (McDowall, 1990).

Vertical connectivity is the linkage between the surface and groundwater in the hyporhoeic zone. It is a critical zone that impacts on ecological processes particularly associated with secondary production where active microbial biofilms and invertebrates that graze on biofilms are found. Hyporhoeic activity may extend well into the riparian zone especially in areas prone to flooding (Boulton, 2007). Riparian zones impact on hyporhoeic activity by moderating sediment input and providing leaf litter and woody debris to the stream. Such debris can alter flow at its site altering the vertical hydrological exchange of nutrients and chemicals. The further development of riffles around logs can provide future habitat for invertebrates and fish.

**Structure and function**

There is considerable debate as to the optimal size and position of a riparian zone with regard to both its length and width. Riparian zones are effective filterers of contaminants from surface run-off if they are wide enough to slow the flow of surface run-off and are able to increase the soil filtration of particulate matter. Such functions are assisted by dense ground cover and litter under trees that ensure the soil has low compaction (Quinn, 2003). Surface run-off increases with increased valley-side slope angles, increased rainfall or animal compaction of the soil.

The concept that the whole catchment of a stream is responsible for stream ecological integrity has led to doubts about the appropriateness of riparian plantings in small sections along a reach. A review of habitat quality and ecological functioning associated with non-catchment riparian buffer zones by Parkyn *et al* (2003), showed that visual water clarity and bank stability had improved but macroinvertebrate assemblages were unchanged. Death & Collier (2007) found that streams emanating from catchments in the Waikato region with 40-60% upstream native vegetation cover, as compared to deforested streams, retained 80% of the mean biodiversity found in pristine forest streams. Their conclusion was that riparian restoration schemes should focus on headwater catchments rather than short segments.

There is also debate as to the optimal composition of the riparian vegetation at any elevation or channel width. Quinn & Scarsbrook (2001) have suggested that a mix of native and exotic trees would provide summer native leaf fall and autumn exotic leaf fall for the macroinvertebrates. The result would be that trees with fast-decaying leaves were planted along streams that flood and a mix of trees with fast and slow-decaying leaves planted in headwater streams.

However, the widespread use of exotic trees, including pine trees, is contentious. The potential for the harvesting of plantation forests to irreparably affect stream ecology was investigated by Collier *et al.* (2004). They compared the colonisation of pinewood and 4 native woods as habitats for epixylic biofilms and aquatic invertebrates, and found that the wood type was not significant in maintaining community compositions but noted that as wood provided essential ecosystem functions in a stream, the rate of decay might in future determine community composition. As pine logs decay more rapidly than native logs, the case for a riparian buffer zone of native trees in a pine plantation may be appropriate.

The ability of riparian vegetation to shade a stream channel decreases with stream width and the height of vegetation (Davies-Colley & Quinn, 1998). Tussock grasses and flaxes only provide shade over channels <2m wide. Mature trees provide a more complete canopy for channels <6m wide but the reduction in lighting from riparian vegetation reduces in-stream primary production and nutrient uptake. Shading of 60-80% of the waterway controls in-stream growth of filamentous green algae and >90% prevents macrophyte growth.

The re-establishment of riparian buffer zones has been widely promoted as a measure to redress the obvious and severe consequences of their loss, including flooding, sediment loading and loss of habitat for flora and fauna due to pollutants. Drewry *et al* (2006) have drawn attention to the importance of allowing natural recovery of soil conditions by exclusion of animals in the riparian zones with the consequent reduction of sediment load. In New Zealand, a "Clean Streams ACCORD" between Fonterra Dairy Cooperative, Local Government NZ, the Ministry for the Environment and the Ministry of Agriculture and Forestry, has successfully provided a framework for encouraging the care of waterways. Regional Councils also have responsibilities and requirements to manage stream habitats under the Resource Management Act (RMA, 1999).

The investigation of two catchments in the South Island where forest fragments were embedded in agricultural landscape confirmed that the effects of agricultural land on stream functioning and macroinvertebrate assemblages were not mitigated even where the forest fragments were 5-7ha (Harding *et al.*, 2006). They further showed that continuous forest supported greater taxonomic richness and concluded that the length of riparian forest was critical to any mitigation of the negative impacts of agriculture.

## River Environment Classification (REC) and Riparian Management Classification (RMC)

Attempts to rationalise riparian management and restoration led to the development of the RMC (Quinn, 1999) which was loosely based on the REC (Snelder *et al*, 1999) using its classes within the template. The REC is a spatial framework that was developed in 1997 to facilitate the grouping of river and stream networks that had similar ecological characteristics though geographically separated, thus enabling similar environmental management (Snelder *et al*, 1999). A hierarchy of six controlling factors - climate, topography, geology, land-cover, network-position and valley-landform - was subdivided into categories that then give a detailed description of the river or stream based on its physical and biological characteristics. These characteristics are widely used for the management of hydrology, water quality and biologic communities across different rivers that have the same profiles (Snelder *et al*, 2004) (Appendix 6).

The RMC was first used as a framework for the Waikato region's riparian zone management of the Piako and Waihou River catchments (Quinn, 1999). It was further developed in 2000 for Canterbury catchments (Quinn, 2003) and refined in 2003 for use in Motueka (Phillips & Marden, 2003). The RMC protocol is based around the current RMC (RMC-C) and potential RMC (RMC-P) of 12 riparian functions seen as essential to improving stream habitat, controlling contaminant input and enhancing biodiversity, aesthetics and recreation. The key factors influencing potential riparian functions identified in Canterbury were stream width, adjacent land slope and whether the stream was ephemeral or perennial. A geomorphic RMC (RMC-G) has been derived for assessment of riparian functions, giving further detailed classification for future management, including valley-form and vegetation types appropriate to stream width.

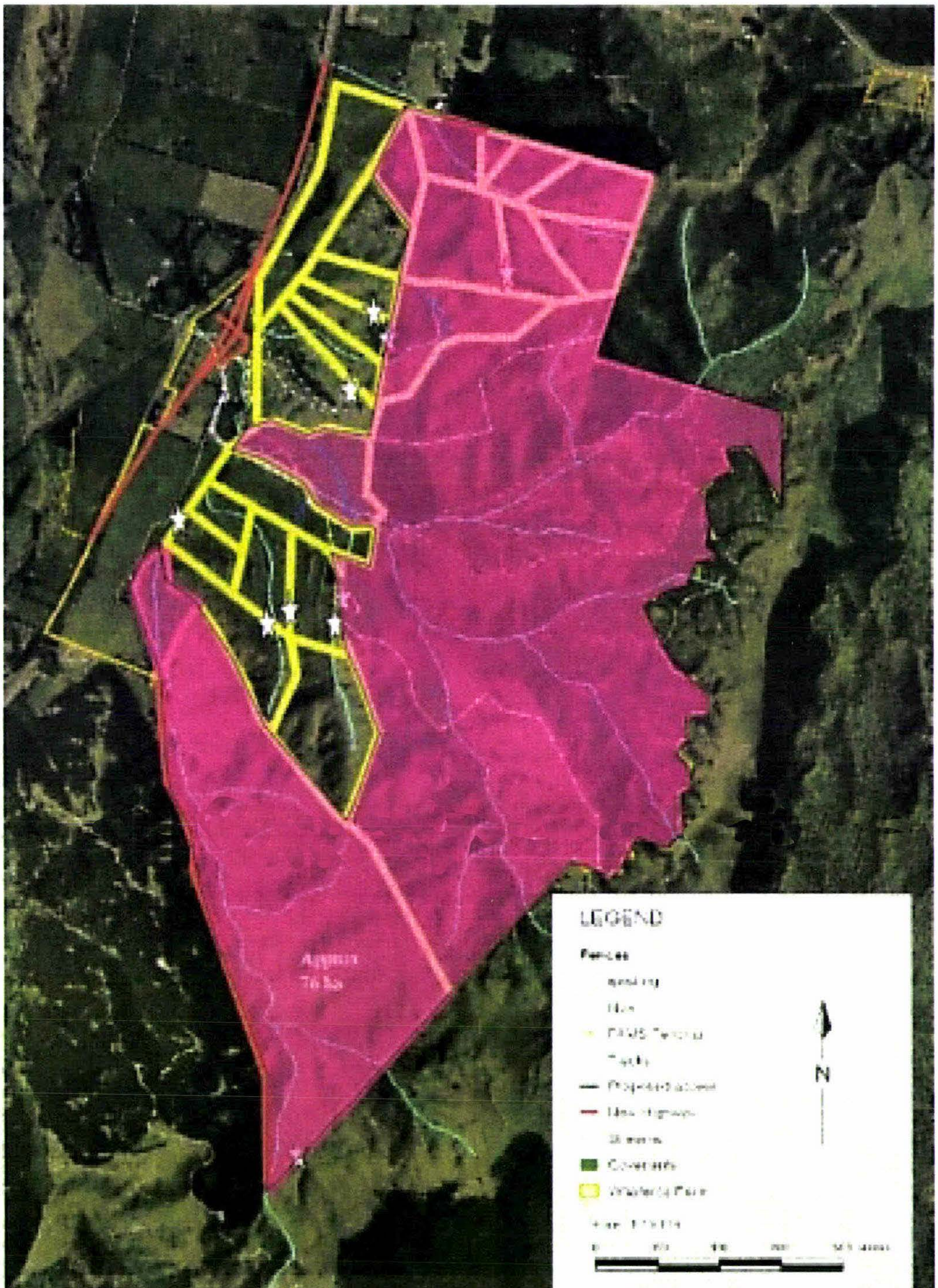
### Whareroa Stream

The Whareroa Stream tributaries arise from an escarpment 272m above sea level and flowed west to the sea through the Whareroa Farm and Queen Elizabeth Park. Whareroa Farm had until recently been used for the fattening of young Angus cattle and sheep. It also has a significant feral population of goats, rabbits, hares, and large numbers of possums. There was collapse of stream banks at hilly sites where cattle had crossed and slipping on the hillsides. Many fences on it were intact but most fencing bore no relationship to the streams or bush remnants and animals crossed the streams and accessed the bush remnants freely.

Weeds were extensive with large areas of gorse and variegated thistle. Some of the higher land had scrub and regenerating native bush, and the moderate hill country had bog and swamp areas scattered throughout it. Remnant stands of bush included kahikatea (*Dacrycarpus dacrydioides*), nikau (*Rhopalostylis sapida*), mahoe (*Melicytus ramiflorus),* kohekohe (*Dysoxylum spectabile*), matai (*Prumnopitys taxifolia*), titoki (*Alectryon excelsus*), kawakawa (*Macropiper excelsum*), karaka (*Corynocarpus laevigatus*) and a few tree ferns. A stand of gum trees was present on the northern side of the farm.

This baseline study assesses the current and potential riparian situation on Whareroa Farm using the REC, RMC-C and RMC-P. Together with the SEV assessment (Chapter 2), it will inform a wider recommended ecological management plan for the farm. The study did not undertake any assessment of the type of vegetation that might be appropriate to refurbish the riparian zones. The Department of Conservation (DOC) is proposing to retire 75% of the catchment, though there is opposition from the 'Guardians of Whareroa' who wish to run an operational farm (Map 3).

**Map 3.** Proposed area of Whareroa Farm to be retired shown in pink (DOC, 2007).



# Research Methodology

## Site Characteristics

The Whareroa Stream catchment of 15.61km$^2$ has a base of greywacke bedrock, deeply incised by its streams. The steep valley sides in all areas are eroded by animal tracks and have superficial slipping. Apart from areas near the woolshed and the shepherd's cottage at a lower elevation, where the riparian strip was fenced, fencing was unsympathetic to restoration of the landscape to bush with streams being very accessible to animals. As a consequence, stream banks were broken and the streams carried increased sediment. Riparian growth other than grass was sparse for most of the area, some reeds and arum lilies occurring. A small wetland swamp area was present near the entrance to the farm with reeds, grasses and gorse. Cattle had free access to remnant bush, bog and swamp areas found on the valley sides.

Three sites on Whareroa Farm and two sites in Queen Elizabeth Park were assessed. They were selected as representative of the general variations in geomorphology of the Whareroa Stream catchment. The sites were described in Chapter 2. Their riparian features are noted below.

**Site A:** The stream banks were 1.5 metre high and the riparian zone was on peat over sand. The banks were mainly grass covered with recent riparian planting of flax (*Phormium tenax*), toetoe (*Cortaderia toetoe*), ngaio (*Myoporum laetum*), taupata (*Coprosma repens*) and karamu (*C. robusta*). The nutrient level of the water was high arising from farm run-off and streams arising in nearby pastures. The peat soils caused water discolouration. The macrophytes, water celery (*Apium nodiflorum)* and watercress (*Rorippa nasturtium-aquaticum*) were excessive (>50%) and in-stream filamentous algae extensive.

**Figure 20.** Site A at the lower reaches of the Whareroa Stream.
New riparian plantings of grasses on both banks.

**Site B:** The riparian zone was on banks 1.5m high on compacted gravels over peat. A seldom used, gravel car track bisected the site. Exotic trees including willow (*Salix babylonica*) and sycamore (*Acer pseudoplanata*), native trees including kawakawa (*Macropiper excelsum*) and mahoe (*Melicytus ramiflorus*) and weedy scrub vegetation including blackberry (*Rubus fruticosus*), convolvulus (*Calystegia silvatica*) and gorse (*Ulex europaeus*) were on the banks. At the upper end of the reach ferns covered the banks. Moderate amounts of water celery and watercress occupied about 40% of the streambed.

**Figure 21**. Site B, showing mixed exotic and native trees, and watercress invasion of the stream.

**Site C:** This site was on a meandering stream with a cobble base in an area that was steep to very steep hill country with moderate rainfall. The valley slope was 26-35°. Watercress occupied 70% of the streambed. The steep valley sides had slumping and cattle damage affecting >90% of the banks (Appendix 8). Grasses, gorse, variegated thistle and weeds occupied the steep banks, with a small number of mahoe, ngaio and dead tree ferns.

**Figure 22.** Site C, Whareroa Farm, on a stream that flows from the Maungakotukutuku Hills

**Site D**: This was on a meandering stream with a cobble base in a steep valley. The only riparian vegetation, apart from grass and weeds, was gorse up to 15m high on left bank. The right bank rose up to 15m high at upper end of reach. There were riffles and pools but minimal wood debris. Watercress occupied 5% of the streambed. The closest fence was 30m from the right bank and cattle had free access. Remnant bush that included kahikatea and nikau palm was on the hillside within 100m.

**Figure 23.** Site D, showing high gorse and steep hillside low banks native trees, and watercress invasion.

**Site E**: This was on the meandering Ramaroa Stream traversing farmland in a steep valley before entering native bush. The land was undulating high terraces and fans with a mantle of loess over consolidated gravels. The stream had a cobble base and flowed beneath a 90% canopy of kohekohe, matai and titoki. There was wood debris and leaf litter in the stream and on the banks. Weeds were slowly invading the edges of bush, especially *Tradescantia fluminensis*. The left bank was 1m high and topped with mature trees and lianas, while the right bank was 15m high topped with mature trees.

**Figure 24.** Site E (Ramaroa Stream) within native bush on Whareroa Farm.

Fieldwork for the study was undertaken on-site in each valley and reach. A worksheet designed to cover the current and potential riparian management was completed (Appendix 7). One visit to Sites C and D with the Biodiversity Manager of Greater Wellington Regional Council ensured consistency of observation with that used in other areas of the Region. Other information necessary for complete riparian assessment was derived from the REC database.

**River Environment Classification (REC)**

The REC uses 6 hierarchical classes defined by one of six factors to describe the characteristics of a stream or river. The factors are Climate, Source-of-flow, Geology, Land-Cover, Network-Position and Valley-Landform. The streams involved in this study were small and of a defined source and therefore only the first spatial level of the classification was used for information in association with the RMC. The data was available from the REC database (Table 17).

**Table 17.** River Environment Classification database definitions (after Snelder *et al.*, 2004)

| | |
|---|---|
| Climate: | Warm (W) = mean annual temperature >12°C |
| | Cool (C) = mean annual temperature <12°C |
| | Wet (W) = mean annual effective precipitation 500 - 1500mm |
| Source-of Flow: | Low (L) = elevation <400m |
| Geology: | Hard sedimentary (HS) |
| Land-Cover: | Pastoral (P) (derived from LENZ classifications) |
| Network-Position: | Low Order (LO) = stream order 1 or 2 |
| | Middle Order (MO) = stream order 3 or 4 |
| Valley-Landform: | High Gradient (HG) = land slope >0,04° |
| | Low gradient (LG) = land slope <0.02° |

**Riparian Management Classification (RMC)**

Data was collected for three spatial scales, namely catchment, valley and reach. Some basic data was available from the REC but on-site field assessment was essential. Characteristics evaluated included wood and leaf litter input, enhancement of fish spawning and general fish habitat, stream bank stability, denitrification of groundwater inflows, overland flow filtering of contaminants, shading of channels for temperature and in-stream plant control, downstream flood control, recreational use and aesthetics (Quinn, 2003). The riparian zone in this study was defined as a strip 10m wide each side of the stream channel.

Assessment and scoring was undertaken according to the protocol in Appendix 9.

- Site elevation and distance from the sea were obtained from NZMS topographic map 260-R26: 1:50,000 (NZSLI 2006).

- Catchment, valley segment, and reach variables and basic data about each stream and reach were obtained from the REC database.

- Classifications of the streams were derived from the REC database using the 6 variables identified as controlling factors (Snelder *et al.*, 2004).

- On-site data for current riparian assessment (RMC-C) was recorded on the field worksheets and included assessment of the valley form, land slope class and drainage, average bank heights, percentages of run/ riffle/ pool, stream bank stability, percentage of undercutting and slumping, presence of riparian wetlands on terraces above channel, dominant riparian species and identification of macrophyte cover. Other relevant information was available from the field worksheets of the SEV assessment. The current situation was rated on a scale of 0 (absent) – 5 (very highly active).

- On-site riparian potential function assessment (RMC-P) was an informed indicative process of judging how the best practicable riparian management (ie. fencing out stock and managing the area with planting of grasses, shrubs and trees within the protected area) might markedly improve the riparian functions. It covered twelve riparian functions – bank stabilization, overland filter flow, plant nutrient uptake, denitrification, shade for in-stream temperature control, shade for in-stream plant control, wood input, leaf litter input, fish habitat, downstream flood control, recreation and aesthetics. The definitions of these functions followed the recommendations of Quinn (1999). They were scored according to a rating scale where their potential was rated as 0 (absent) - 5 (very highly active).

- A sketch of the stream cross sections, documentation of any unique features, and comments relating to current or future management of the riparian zone were recorded at each site (Appendix 10).

- Assessment of effective shading for stream width (Table 18).

**Table 18**. Effective shade for various channel widths (after Quinn, 2003).

| *Channel width* | **Stream size** | **Effective shade** |
|---|---|---|
| <2m | tiny 'T' | Tussock, tall grasses |
| 2 - <6m | small 'S' | High shrubs |
| 6m - <12m | medium 'M' | Trees |
| >12m | large 'L' | None |

In addition to the parameters required for the RMC-C and RMC-P, other measures of stream health relating to riparian management were measured.

**Temperature variation**

Onset Hobo H8 temperature loggers placed at each reach in a deep site measured variability in daily water temperatures. They were removed after 6 months and the information decoded to show daily maximum and minimum temperatures. Temperature variability is greatest with lack of riparian cover to a stream or may be seen where there is a dense canopy under which a stream flows. Where variability is great, the assemblages of fauna can be markedly reduced or absent.

**Turbidity**

Turbidity results from the effect of suspended sediment on light passing through water. It was measured using a 1m long, 50mm diameter, clear acrylic clarity tube, graduated along its length in centimetres, and with a black magnetic disc in the tube. A direct reading on the tube indicated the degree of turbidity.

**Conductivity**

The conductivity of the stream water was measured using a EUTECH Cybernetics TDScan 3, 0 1990 μS, automatically adjusted to 25°C. The result is a measure of the ability of water to conduct an electrical current and is affected by the presence of inorganic dissolved solids such as chloride, nitrate, phosphate, sodium, calcium and iron. It may also be affected by water temperature, increasing with warmth, and will reflect ions gleaned from the bedrock through which it flows, with clay soils giving high conductivity. Changes in conductivity can indicate pollution particularly with nitrate or phosphate

**pH**

pH was assessed using Merck Neutralit strips (pH 5-10). These strips measure in 0.5 units, and after immersion for 10 minutes the colour is compared with the reference colours on the packet to give a reading. The pH is a measure of the acidity of the water providing information about litter decomposition, or soils (peat) causing acidification, and thus unable to sustain some assemblages of fish and/or aquatic invertebrates. It can also indicate the presence of pollutants, acid or alkaline, that may have entered the water either from animals or anthropogenically.

**Weed species**

An inventory of weed species within the riparian zones was assembled for each site using dedicated reference books (Bishop & Bishop, 1994). A history of a more than a century of topdressing, and cattle and sheep farming meant that there were likely to be widespread weeds, many of little concern but some were noxious, such as hemlock and ragwort, or requiring extinction, such as the variegated thistle (*Sybilium marianum*) (Figure 29). A biodiversity survey of the farm in April 2007, by the Greater Wellington Biodiversity Unit and DOC, provided some further details of vegetation on the farm (Appendix 9).

# Results

## River Environment Classification (REC)

The REC database classifications of the streams were as shown in Table 17:

- there were three low order (LO) streams (C, D, and E) and two middle order (MO) stream (A and B).
- the valley landforms were high gradient (HG) for the Whareroa Farm streams (C, D & E) i.e. a slope of >0.04 but low gradient (LG) for the stream sites A and B on Queen Elizabeth Park (QEP) i.e. gradient of <0.02.
- the NIWA classification of mean annual temperatures and annual effective precipitation indicated that the Whareroa Farm sites A, B and C and site B in Queen Elizabeth Park, were defined as cool-wet (CW) i.e. mean annual temperature <12°C and rainfall 500-1500mm, while site A was warm wet (WW) i.e. a mean annual temperature >12°C. Evaluation of the recorded average temperatures, however, suggested that this was not the situation for the 6 months November 2006 – May 2007, as discussed later.
- the source-of-flow was low elevation (L) as it was less than 400m above sea level.
- the land cover class was pastoral (P)
- the geology was hard sedimentary (HS).

**Table 19.** River Environment Classification (REC) of the Whareroa Streams in order of impact on environment. (Snelder *et al*, 2004)

| **Factor \Site** | **A** | **B** | **C** | **D** | **E** |
|---|---|---|---|---|---|
| Climate | WW | CW | CW | CW | CW |
| Source-of-flow | L | L | L | L | L |
| Geology | HS | HS | HS | HS | HS |
| Land-Cover | P | P | P | P | P |
| Network-Position | MO | MO | LO | LO | LO |
| Valley-Landform | LG | LG | HG | HG | HG |

The full REC classification was therefore:

Climate/Source-of-Flow/Geology/Land-cover/Network-Position/ Valley-Landform.

| | | | |
|---|---|---|---|
| Site A | WW/L/HS/P/MO/LG | Site D | CW/L/HS/P/LO/HG |
| Site B | CW/L/HS/P/MO/LG | Site E | CW/L/HS/P.LO/HG |
| Site C | CW/L/HS/P/LO/HG | | |

**Riparian Management Classification (RMC)**

Each stream site was visited to assess its current and potential riparian health, and environmental factors affecting it noted (Appendix 8). The general characteristics of all sites were scored and tabulated according to the RMC protocol (Table 20). All stream sites were perennial, though flows were low in late summer.

The dominant riparian vegetation was grass and weeds at sites A, C, and D. Mature exotic and native trees were present on one bank at site B and native trees on both banks at site E. Plantings of flax, grasses and small native shrubs had begun at Site A. There were no wetland areas at the study sites but downstream of site C were some *Carex secta* plants 1.5m tall in a bog (Figure 25). Gorse was present at site C in patches and occupied the left bank of site D.

**Figure 25.** *Carex secta* 1.5m high, in bog near site C

**Table 20.** Summary of stream and riparian characteristics of each site. (See Appendix 8 for definitions and scoring. Quinn, 2003)

| Attribute | Site A | Site B | Site C | Site D | Site E |
|---|---|---|---|---|---|
| **Catchment** | | | | | |
| Catchment mean slope (°) | 12.98 | 16.46 | 20.34 | 20.44 | 21.15 |
| Source of flow index | 1 | 1 | 2 | 2 | 2 |
| Dominant baserock geo index | 1 | 5 | 5 | 5 | 5 |
| Catchment area ($km^2$) | 15.61 | 6.91 | 1.25 | 1.01 | 1.27 |
| Catchment land cover index | 3 | 3 | 6 | 6 | 6 |
| **Valley segment** | | | | | |
| Riparian land use | cattle | cattle | cattle | cattle | cattle |
| Channel shape category index | 1 | 2 | 3 | 3 | 3 |
| Valley bottom width cat. index | 6 | 6 | 2 | 3 | 4 |
| Segment elevation (m a.s.l.) | 16 | 19 | 154 | 161 | 65 |
| Segment land slope (°) | 6.47 | 6.47 | 25.25 | 24.25 | 20.11 |
| Stream order | 4 | 3 | 1 | 1 | 2 |
| Domain soil age class | 1 | 1 | 1 | 1 | 1 |
| Local mean air temperature | 13.59 | 11.64 | 11.31 | 11.05 | 11.23 |
| Domain land drainage class | 2 | 2 | 3 | 3 | 4 |
| Domain acid P class | 1.51 | 1.46 | 1.02 | 1.31 | 1.13 |
| Domain induration | 2.55 | 2.96 | 3.9 | 3.03 | 3.6 |
| **Reach** | | | | | |
| Water width (m) | 5.43 | 3.82 | 1.00 | 1.00 | 2.68 |
| Nonvegetated channel width | 5.43 | 4.32 | 0.30 | 1.57 | 0.60 |
| Flood plain width (m) | 4.13 | 2.55 | 0.73 | 4.23 | 1.86 |
| Wet/dry index | 1 | 1 | 1 | 1 | 1 |
| Bankfull width (m) | 9.55 | 6.06 | 2.09 | 1.50 | 3.28 |
| Local slope index | 3 | 3 | 4 | 4 | 4 |
| Local land slope length index | 1 | 1 | 3 | 3 | 3 |
| Substrate composition | Silt/bedrock | cobble | cobble | cobble | cobble |
| Channel slope index | 3 | 3 | 6 | 6 | 6 |
| Vegetation height (m) | 0.5 | 5.0 | 1.0 | 5.0 | 15.0 |
| Shade ratio | 0.03 | 0.51 | 0.71 | 3.3 | 2.09 |
| Bank height right bank (m) | 1.0 | 1.5 | 1.0 | 2.0 | 5.5 |
| Bank height left bank (m) | 1.0 | 1.6 | 1.0 | 1.3 | 1.0 |
| Mean bank height (m) | 1.0 | 1.55 | 1.0 | 1.65 | 3.25 |
| Macrophyte cover % | 50 | 40 | 70 | 5 | 0 |
| Dominant riparian veg. index | 1 | 4 | 1 | 3 | 9 |
| Periphyton index | 4 | 0 | 3 | 1 | 1 |
| Woody debris index | 0 | 1 | 1 | 1 | 1 |
| Stable bank % | 100 | 100 | 10 | 100 | 100 |
| Stock access to left bank index | 0 | 0 | 1 | 1 | 0 |
| Stock access to right bank | 0 | 0 | 1 | 1 | 0 |
| L & R banks stock access index | 0 | 0 | 2 | 2 | 0 |
| Stock bank damage index | 0 | 0 | 3 | 2 | 0 |
| Fence type index | 3 | 3 | 0 | 0 | 3 |
| Fence to left bank (m) | 30 | 400 | 0 | 0 | 10 |
| Fence to right bank (m) | 100 | 30 | 0 | 0 | 40 |
| Both sides fenced (%) | 100 | 100 | 0 | 0 | 100 |

**Riparian Management Classification - Current (RMC-C) and Riparian Management Classification - Potential (RMC-P)**

Current and potential riparian activity assessed on-site is summarised in Table 21 (Quinn, 2003). The potential riparian function was judged the 'best outcome for the best practicable management for the site'. The results clearly show degraded riparian zones at all the stream sites though site E had the best current assessment (RMC-C). The least active functions currently were shading and leaf litter and wood input while the most active were bank stabilization and overland flow filtering. The priority improvements of function expected across the five sites with riparian restoration and best practice management, were – shading (for temperature, plants, wood input, leaf litter, and fish habitat) > nutrient uptake > denitrification > downstream flood control > bank stability and overland filter flow > aesthetics > recreation (Table 22).

**Figure 26.** Site C - Cattle damage to the banks, excessive watercress and algal growth in stream

The results (Table 21) were influenced by the current, very poor functions at site C with only 10% bank stability and 90% slumping, minimal effective shade for fish cover, poor wood and litter input, and poor capacity for denitrification (Figure 26). However, it had the best potential (RMC-P) for the future with stock removal, fencing and a positive restoration plan. The effects of no riparian input was also seen at site D. Across all sites the recreational and aesthetic assessment score was low but the potential for improvement was high as a result of improvements by riparian restoration.

**Table 21.** Summary of current (RMC-C) and potential (RMC-P) riparian activity at sites on the Whareroa Stream. Scores range from 0 = not active to 5 = very highly active

| Function\ Site | A | B | C | D | E | Mean |
|---|---|---|---|---|---|---|
| **Current function** | | | | | | |
| Bank stability_C | 4 | 4 | 1 | 5 | 5 | 3.8 |
| Overland flow filtering_C | 3 | 4 | 3 | 4 | 5 | 3.8 |
| Nutrient uptake_C | 3 | 3 | 2 | 4 | 4 | 3.2 |
| Denitrification_C | 2 | 2 | 1 | 2 | 4 | 2.2 |
| Shade for temp_C | 0 | 4 | 1 | 3 | 5 | 2.6 |
| Shade for plant control_C | 0 | 4 | 1 | 3 | 5 | 2.2 |
| Wood input_C | 0 | 2 | 1 | 0 | 3 | 1.2 |
| Litter input_C | 0 | 2 | 0 | 0 | 3 | 1.0 |
| Fish habitat_C | 3 | 3 | 0 | 3 | 3 | 2.4 |
| Downstream flooding_C | 2 | 1 | 0 | 2 | 2 | 1.4 |
| Recreation_C | 0 | 2 | 0 | 0 | 2 | 0.8 |
| Aesthetics_C | 2 | 2 | 0 | 2 | 3 | 1.8 |
| **Mean for each site** | **1.6** | **2.8** | **0.8** | **2.3** | **3.6** | |
| **Total for each site /60** | 19 | 33 | 10 | 28 | 45 | |
| | | | | | | |
| **Potential functions** | | | | | | |
| Bank stability_P | 5 | 5 | 5 | 5 | 5 | 5 |
| Overland filtering_P | 5 | 5 | 5 | 5 | 5 | 5 |
| Nutrient uptake_P | 5 | 5 | 5 | 5 | 5 | 5 |
| Denitrification_P | 3 | 4 | 4 | 3 | 5 | 3.8 |
| Shade for temp_P | 1 | 5 | 5 | 5 | 5 | 4.3 |
| Shade for plant control_P | 3 | 5 | 5 | 5 | 5 | 4.8 |
| Wood input_P | 1 | 5 | 5 | 5 | 5 | 4.3 |
| Litter input_P | 2 | 5 | 5 | 5 | 5 | 4.4. |
| Fish habitat_P | 5 | 5 | 5 | 5 | 5 | 5 |
| Downstream flooding_P | 3 | 2 | 2 | 2 | 2 | 2.8 |
| Recreation_P | 3 | 5 | 2 | 2 | 5 | 3.4 |
| Aesthetics_P | 4 | 5 | 5 | 4 | 5 | 4.6 |
| **Mean for each site** | **3.3** | **4.7** | **4.4** | **4.3** | **4.8** | |
| **Total for each site /60** | 40 | 56 | 53 | 51 | 57 | |

**Geomorphological factors**

The factors influencing geomorphological function ratings were channel width, permanence of flow and slope of land adjacent to the riparian zones.

**Flow** – all streams were perennial with lower flow in the summer. At Site D, a pipe 10cm diameter extracted water at the lower end of the reach for an historic reservoir supplying stock water. The flow above and below the pipe was not affected and there was no damming on the first. However, a second visit in May 2007, found the stream completely dammed, all water diverted to the reservoir and no flow downstream.

**Table 22.** Potential for change - average improvements of function expected across the five sites. Priority Ratings for change: L = Low; M = Moderate; H = High.

| **Function** | **Mean RMC-C** | **Mean RMC-P** | **Potential for change (RMC-P – RMC-C)** | **Priority ratings** |
|---|---|---|---|---|
| Bank stability | 3.8 | 5.0 | 1.2 | L |
| Overland filter flow | 3.8 | 5.0 | 1.2 | L |
| Nutrient uptake | 3.2 | 5.0 | 1.8 | M |
| Denitrification | 2.2 | 3.8 | 1.6 | M |
| Shade for temperature | 2.6 | 4.3 | 1.7 | H |
| Shade for plant growth | 2.2 | 4.8 | 2.6 | H |
| Wood input | 1.2 | 4.3 | 3.1 | H |
| Leaf litter | 1.0 | 4.4 | 3.4 | H |
| Fish habitat | 2.4 | 5.0 | 2.6 | H |
| Down-stream flood control | 1.4 | 2.8 | 1.4 | M |
| Recreation | 0.8 | 3.4 | 2.6 | L |
| Aesthetics | 1.8 | 4.6 | 2.8 | L |

**Channel width** – all study sites had bankfull channel widths of <12m, the greatest being Site A with 5.43m (Table 23). Geomorphic channel width classifications provided a guideline to effective shading. None of the sites were >12m wide indicating that effective shading could be established. The potential for effective shading was greatest at Site C.

**Table 23.** RMC-C and RMC-P associated with channel width of sites

| Site | Channel width | Current riparian | Potential riparian |
|---|---|---|---|
| A | 9.55m = M | Grasses & shrubs | Grasses/ shrubs |
| B | 6.06m = S | Trees & scrub | Trees |
| C | 2.09m = S | Grass | Small trees/ shrubs |
| D | 1.50m = T | Grass & gorse | Small trees/ shrubs |
| E | 3.28m = M | Trees | Trees |

**Local landform** – local landform is a key morphological factor in riparian function as it accounts for surface water run-off. Thus the U-shaped and V-shaped valleys (C, D, E) had higher ratings than plains to decrease run-off (Appendix 10). Sites A and B drained medium sized plains with compaction over sand and peat. Site C had considerable run-off from the steep valley sides bereft of any trees and with slumping and springs. Site D had good overland filter flow through gorse and grasses and Site E had low run-off through trees (Appendix 8).

**Temperature variations**

The Hobo H8 temperature loggers were retrieved from all the sites 185 days after insertion in the deepest part of the reaches. Unfortunately, the logger at site C had leaked and there was no data for that site. The data from the other four loggers showed high maximum temperatures at all sites (21.35°C-26.34°C) suggesting that either periods of low flow had occurred where they were not completely covered or the water in the upstream catchments was subject to high daily temperatures through lack of riparian protection. All the farm streams were shallow and heated quickly if exposed to solar radiation.

Average minimum temperatures were also higher than expected, >9.03°C (9.03°C-10.6°C) possibly reflecting the warm dry season with warm nights that persisted through to the end of May 2007. The average temperatures for all sites indicated a possible shift from previous REC classifications where Sites B, C, D and E were classified as CW (cool-wet) ie. average temperatures <12°C. The diurnal temperature swings were greatest in the exposed streams eg. site D temperature amplitude varied from 11.11°C to only 0.38°C, and site A from 14.15°C to 0.38°C. The least affected was site E that was within a bush area. Large diurnal temperature swings have negative implications for the survival of fish and macroinvertebrates (Figures 18, 19, 27).

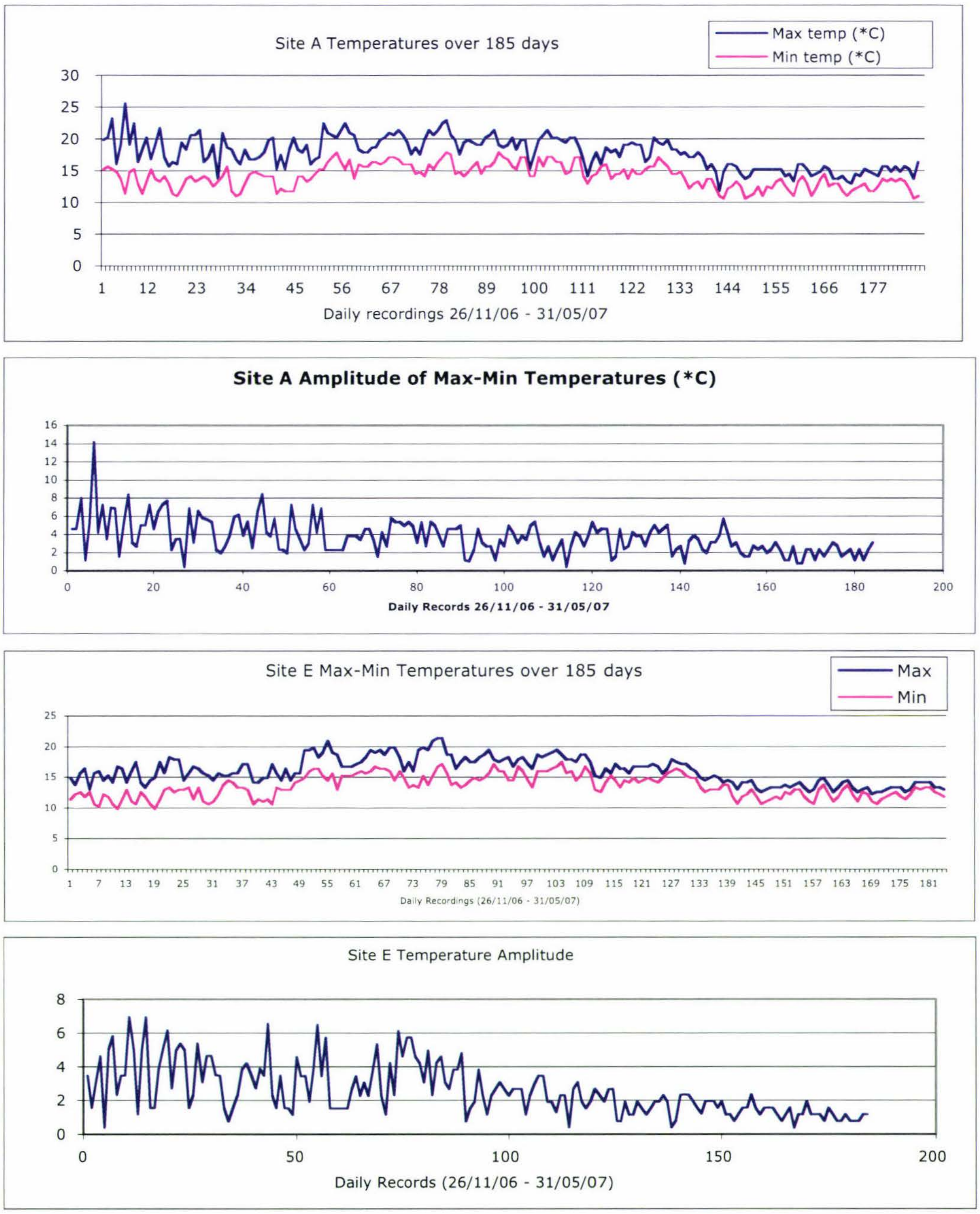



**Figure 27.** Maximum-minimum temperature variations and amplitudes at sites A and E over185 days from 26/11/06 to 31/05/07.

**Turbidity**

Water clarity, as a function of the effectiveness of riparian function, was measured at each site on one occasion only, using a clarity tube. The length of vision within the tube was measured in cm and compared to the scale. The variation between sites was small, and within the range of "slightly turbid" on the day of the survey (Table 15).

The apparent clarity of the water at Site C in spite of bank damage by cattle (Figure 26) was associated with no farm animal movement near the sites on the week before testing. However, a population of recently dead, but intact, land slugs in the stream bore testimony to recent bank destruction.

Site D was the clearest stream, with little stock movement nearby, a rocky base and riffles and pools. The riparian vegetation was sparse above and below the reach and though there was only gorse at the study site it had effective filtering activity.

**Conductivity**

This was measured at each site using the EUTECH Cybernetics TDScan 3 adjusted to 25°C. Measurements taken at each study site showed increased conductivity as the network streams became larger and absorbed water from tributaries draining farmlands.

The measurements were recorded as microsiemens per centimetre (μS/cm). Sites A and B measurements indicated slight to moderate enrichment of the water. Site A had considerable amounts of green filamentous algae during the summer. Sites C, D and E had slightly enriched waters, with Site C having some green filamentous algae over the summer. The total lack of riparian vegetation and the large amount bank slumping and cattle damage at Site C, were not consistent with this measurement that was expected to be greater (Table 16).

**pH**

The pH of the stream water was measured at each site with Merck Neutrality pH strips and found to be the same at all sites, namely pH = 7.5, which is neutral (neither acid nor alkaline). The incremental change on the tape was 0.5 units and therefore relatively insensitive to small differences. The readings were undertaken in the late mornings each time. The presence or absence of macrophytes did not alter the readings, nor did the presence or absence of farm run-off or peat soils (Table 16).

**Riparian vegetation**

An inventory of the weeds on the riparian zones up to 10m from the stream bank sites was compiled (Appendix 11). They were mainly the common pasture weeds introduced either with seed or animals. Variegated thistle was abundant at Site C (Figure 28) and inkweed and hemlock at Sites D. Foxgloves were widespread over the banks at Sites C and D. Gorse was abundant at Site D and present in patches on the valley sides at Site C. The only weed at Site E was one arum lily, probably washed downstream during high flow and present at the edge of the site.

**Figure 28.** Variegated Thistle (*Sylibum marianum*) on Whareroa Farm

The grasses at Sites A, C and D were pasture grasses, with some native grasses at Site A. Riparian planting had commenced at Site A with flax, toetoe, as well as karamu, taupata and ngaio (Table 24). The macrophytes water celery and watercress, were abundant at Site A and moderately abundant at Site B. Water cress alone was extensive at Site C and moderately abundant at Site D. Other non-weedy macrophytes included reeds and rushes at Site A. There were no macrophytes at Site E.

A list of native trees, at or near each site, was compiled in conjunction with a biodiversity sweep by the Greater Wellington Regional Council in 2007 (Appendix 9). A subsequent visit to the farm by the Wellington Botanical Society in November, 2007, has augmented the list, including plants found in and around the wetland near the entrance and new listings from the bush remnants (Appendix 12). The dominant riparian species across the sites are seen in Table 24 and the distribution of vegetation types in Figure 29.

**Table 24.** Current dominant riparian vegetation list.

| Site | Dominant Species | Prominent species |
|---|---|---|
| A | Grasses | Flax (*Phormium tenax*)<br>toetoe (*Cortaderia toetoe*), |
| B | (mixed trees exotic and native on the stream banks) | sycamore (*Acer pseudoplanata*),<br>willow (*Salix babylonica*),<br>macrocarpa (*Cupressus macrocarpa*<br>kawakawa (*Macropiper excelsum*)<br>mahoe (*Melicytus ramiflorus* |
| C | Pasture grasses | Weeds<br>Variegated thistle (*Sybilum marianum*)<br>Gorse (*Ulex europeaus*) |
| D | Pasture grasses | Weeds<br>Gorse |
| E | Tall native trees –<br>kohekohe (*Dysoxylum spectabile*),<br>titoki (*Alectryon excelsus*),<br>matai (*Prumnopitys taxifolia*) | Understorey ferns and lianas including rata (*Metrosideros perforata*) |

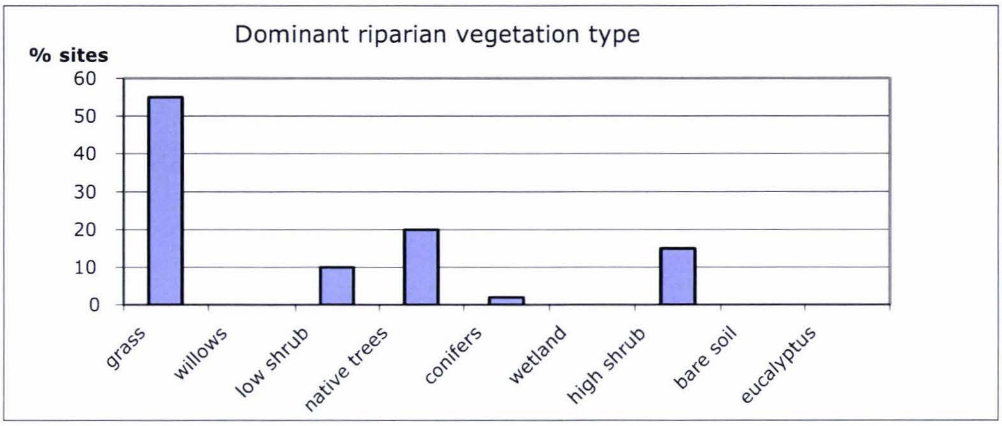



**Figure 29**. Dominant riparian vegetation types across all sites (after Quinn, 2003).

## Summary of results

### River Environment Classification (REC)

**Climate**: results indicated a possible change in the climate of the stream network with warmer temperatures recorded over the 6 months of the survey. Temperatures ranged from 26.34°C maximum at site D to 9.03°C minimum site B. The greatest amplitude of temperature change was at 14.5°C at site A. The mean temperatures ranged from 14.56°C at site E to 15.79°C at site A.

**Topography (Source-of-flow):** eastern hills 272m a.s.l. graded (<400m a.s.l.)

**Geology:** hard sedimentary (greywacke)

**Landcover:** pastoral

**Network-position:** sites A and B were MO (middle order) streams;

sites C, D and E were LO (low order ie. small) streams.

**Valley-landform:** Sites A and B were LG (low gradient)on plains;

sites C, D and E were HG (high gradient) in V-shaped valleys.

### Riparian Management Classification (RMC)

**RMC-C**: the evaluation of the current riparian state over 12 parameters (0=inactive to 5=highly active) gave a possible total score of 60. The mean score obtained over the 5 sites was 27/60. The means across all sites were low for all functions (Table 21) ranging from 0.8/5 for recreation to 3.8/5 for bank stability and overland filter flow.

Site C was an outlier in all results and responsible for the low means. Bank stability was a major problem with severe slumping and stream bank damage (1/5).

Lack of stream shading, impacted on temperature control, wood input, leaf litter input and fish habitat leading to low scores particularly at sites A, C and D,

Recreation and aesthetics had universally poor scores.

Lack of effective riparian activity accounted for the low scores for mitigation of downstream flooding and low nutrient uptake across all sites.

**RMC-P:** the assessment of the potential for restoration (scored by the same method) showed that there was considerable potential for riparian restoration particularly at site C (Table 22). The cumulative RMC-P score was 51.4/60 given best practice management over >10years (Table 21). The establishment of shading at all sites was found to be the most important restorative function as it provided temperature control, organic matter and a favourable habitat for fish. The restoration of a riparian zone would also assist with nutrient uptake, denitrification and downstream flooding.

### Turbidity, conductivity and pH

Turbidity and conductivity were both slightly raised at sites A and B, representing increased nutrient and sediment load. The pH was unaffected.

### Vegetation survey

The dominant vegetation was pastoral grass except at site E where there was native bush. The dominant macrophytes were water celery and watercress except at site E where none were found. No wetland areas were present at the survey sites but were nearby at site C where tussock and *Carex secta* were present. Remnant bush on the valley sides near site D and at site E was of lowland forest with kahikatea, nikau, mahoe, kawakawa, and titoki.

**Table 25:** Summary of riparian ratings of 5 sites. (N/A = not available).

| **SITE** | A | B | C | D | E |
|---|---|---|---|---|---|
| RMC-C (n/60) | 19 | 33 | 10 | 28 | 45 |
| RMC-P (n/60) | 40 | 56 | 53 | 51 | 57 |
| Mean Temp. amplitude (°C) | 3.62 | 4.45 | N/A | 3.18 | 2.50 |
| Maximum amplitude (°C) | 14.15 | 10.73 | N/A | 11.11 | 6.94 |
| Minimum amplitude (°C) | 0.38 | 0,77 | N/A | 0,38 | 0,38 |
| Turbidity (clarity) (cm) % | 70 | 75 | 75 | 80 | 75 |
| Conductivity (μS/cm) | 230 | 210 | 190 | 190 | 190 |
| pH | 7.5 | 7.5 | 7.5 | 7.0 | 7.5 |
| Current shading (n/5) | 0/5 | 4/5 | 1/5 | 3/5 | 5/5 |
| Macrophytes (%streambed) | 50 | 40 | 70 | 5 | 0 |
| Current in-stream organic matter | 0/5 | 2/5 | 0/5 | 0/5 | 3/5 |
| Fencing both sides (%) | 100 | 100 | 0 | 0 | 100 |

A review of the results indicated that site E was the most favourable site with riparian functions – shading, water clarity, lower daily temperature amplitudes, no macrophytes and some organic matter within the stream. It also confirmed that sites A and C were currently the worst sites for riparian and stream health.

## Discussion

This study highlights the critical importance of riparian zones in providing for the ecological health of streams through the interface with water and land that is represented by longitudinal, lateral and vertical connectivity. The impact from the loss of the riparian connectivity resulting in loss of effective protection for streams is well illustrated on Whareroa Farm.

The evaluation of the riparian conditions associated with the south branch of the Whareroa Stream using the REC Protocol (Snelder *et al.*, 1999) and the RMC Protocol (Quinn, 2003) provided clear evidence of the degree of degradation that had occurred. The streams had been subjected to almost complete deforestation over more than a century of farming. The survival of a few small remnant bush areas could provide a basis for restoration and rehabilitation with best practice management in place.

The REC protocol followed the spatial framework established by Snelder *et al.* (1999), with its hierarchy of 6 controlling factors. Climate, including temperatures and rainfall, is seen as the first of the hierarchical factors providing influence over the other five. Analysis of 6 months of temperature data showed higher average temperatures than predicted by the REC database for all sites. The size of the amplitude of temperature change is of concern as it may impact on the fish and invertebrate populations adversely, especially in the presence of low flow. The high maximum temperatures and lower than average rainfall for the district, were likely to have been part of the current El Nino weather cycle (NIWA, 2007). The permanence of such climate changes in a global setting cannot be predicted.

The consequences of the warm temperatures and lowered stream flows were highlighted by the presence of increased filamentous algal, excessive growth of macrophytes and changes in aquatic invertebrates assemblages at the study sites (Table 5). Many previous studies have highlighted the importance of appropriate temperature control on stream ecosystems (Quinn *et al.*, 2000; Townsend *et al.*, 2003; Allan, 2004). However, in spite of the 100m bush cover at site E, daytime stream temperatures were frequently above average probably due to the valley above site E having no riparian stream protection. The length of riparian zones required to adequately maintain an appropriate water temperature for aquatic invertebrates is unknown but Rutherford *et al.* (1999) indicated that 1-5 km may be required for first order streams with 75% shade to achieve a 5°C reduction in water temperature. (Parkyn *et al.*, 2003).

Although there were no apparent changes in the other REC database parameters for each site, they did vary between the sites on the Whareroa Farm with their high gradient, low order streams in steep V-shaped valleys, and the sites in Queen Elizabeth Park with their low gradient, middle order streams on a flat (plain) landform.

The REC information gained was used as part of the RMC protocol to evaluate the riparian functions of the stream network. The 12 riparian functions of the RMC showed the catchment, valley and reach network of the Whareroa Stream to be lacking in its riparian functions (Table 21). No current riparian function (RMC-C) was satisfactory though bank stability and overland flow filter were the better functions across the sites. The overall current activity of all the sites was broadly in line with the results found in Canterbury by Quinn (2003), with the Whareroa Streams showing low ratings for input of wood debris and leaf litter, downstream flooding control, recreation and aesthetics, and low-moderate ratings for shade and denitrification (Table 21).

There was a clear difference between the riparian situation at site C and the other sites with poor or nil ratings for every function except the overland flow filter function. The potential for this stream was, however, very high for most functions with best practicable management. The withdrawal of cattle, effective feral animal control and positive bush restoration would be required to ensure bank stability and a satisfactory fish habitat. Macrophyte (watercress) and weed control, especially variegated thistle, would follow effective shade being established. Scarsbrook and Halliday (1999) have shown that stream ecosystems recover rapidly with the change of land-use from pasture to forest and while it is not possible to define exactly how wide a forest zone needs to be, forest agencies have suggested 10-30m (Broadmeadow & Nisbet, 2004). However, it may take 15-20 years for decreases in daily maximum temperatures levels to be suitable for sensitive macroinvertebrate species (Collier *et al.*, 2001).

The rate of heating unprotected streams decreases with their depth but the benefits of stream shading decreases with width (Davies-Colley & Quinn, 1998). This study did not show great variations in the speed of heating of streams but did show highest maximums occurring in the late afternoons. The plantings of grasses and small shrubs along the banks of streams does not alter the shading but does provide other riparian functions such as overland flow filtering. Mature trees forming a canopy will shade a stream less than 6m wide and incised streams without riparian foliage benefit from topographic shade (Rutherford *et al.*, 1999). This latter may have been important at site D.

The prevention of filamentous algal growth requires 60-80% shade and macrophyte control occurs when 90% shade is present. Results showed that there were no macrophytes at site E though all other sites had considerable quantities. The presence of excessive macrophytes in streams may also illustrate increased nutrient and sediment loads not being processed by riparian mechanisms. Important vertical connectivity between surface water and groundwater involving leaf litter may be overwhelmed by nutrient loads in streams and hence loss of primary production (Boulton, 2007). The build-up of nutrients and sediment contributed to the macrophyte growth at site A.

The presence of increased nutrients and sediment could also be inferred from the slightly raised turbidity and conductivity at sites A and B. Denitrification had only a low-moderate rating across all sites but the potential for change was not large. The lack of riparian plants to provide a carbon source from buried organic material, or wetland areas to provide low oxygen conditions, meant that it was a relatively inactive function at the sites. The nearly complete canopy shading at site E may have limited the in-stream primary production of dissolved nutrients at that site. When shade is restored to streams, there can be an increase in the export of nutrients downstream (Rutherford *et al.*, 1999). Water chemistry does not alter rapidly between protected and unprotected reaches and may be unchanged for more than 300m into a forest remnant from pasture (Scarsbrook & Halliday, 1999).

Lateral connectivity associated with filtering contaminants (including nitrates) from overland flow is compromised where there is surface run-off from steep slopes but enhanced where there is flat land, dense ground cover or forest litter, or porous soils. Compaction of land will also reduce the filtering capacity of the land. Site C is an example of both a steep valley run-off and animal compaction at the stream edges. High overland flow leads to significant stream contamination with the loss of nutrients and sediment from pastoral land without riparian buffering (Drewry, 2006). Several studies have drawn attention to the importance of lateral connectivity in maintaining stream structure and function and flood-plain functions for insects and galaxiids, with continuous forested riparian zones (Storey & Crowley, 1997; Lake *et al.*, 2007).

The channelisation of streams can be a major factor in the prevention of any coarse (>1mm) particle organic material, such as leaves and twigs, being retained in the stream as a food source for macroinvertebrates. The particulate material travels with the velocity of the water and is lost to the site (James & Henderson, 2005). This was demonstrated in the SEV assessment of the study sites. In particular, Site A demonstrated this feature with its paucity of invertebrates and lack of structures to retain material. The channelisation of part of site B was less affected as the cobble base and some branches and snags provide effective 'barriers'.

The dominant riparian vegetation was grasses and weeds except at site E (Table 24). This reflected the current use as functioning farm and parkland areas. Free-roaming cattle on the farm ensured that there was little or no regeneration of native trees and shrubs, and that the stream banks were often severely damaged. Within the park, the channelised banks were protected by remote fencing preventing animal invasion, but were prone to occasional flooding.

Overall, the highest potential for change (RMC-P) identified in this study was with the increased input of wood debris and leaf litter from trees. Though large wood debris is best retained in small streams, this was not the case at site E where tree falls were mostly on the banks and not in the stream. Site E had good leaf fall, bank undercuts and some pools but few fish when surveyed (Table 12) possibly due to upstream conditions including pollution from cattle and warm temperatures. Natural restoration of woody debris to streams may take decades but the process can be sped up artificially (Quinn, 2003). The RMC-P assessment indicated the possibility of large shifts in the management goals for the Whareroa Farm. Quinn (2003) defined 'best practicable management' as the use riparian fencing to prevent stock access and managing the protected area for the development of long grasses and trees as appropriate to the site.

**Summary**

A summary of the individual site's current and potential riparian activities indicates that there is potential for increased riparian activity at all sites (Table 21). The streams all showed the effects of loss of riparian cover either directly above the reach or upstream. The loss of headwater bush and trees affected the entire watershed.

The current riparian activity at site A was marked by the total lack of shade allowing water temperatures to rise, excessive macrophyte growth in the spring and consequent eutrophication of the site in late summer. Though grasses and shrubs have already been planted along its banks, these will take time to be effective contributors to the stream temperatures and litter input. There is little evidence that its present quality provides a suitable habitat for fish and macroinvertebrates, though as a passage to higher reaches it appears to be effective ie longitudinal connectivity is intact. The banks do not provide well for lateral connectivity through the macrophytes but some very small areas of reeds suitable for spawning do exist. The lack of leaf litter on a bed of sediment suggests that vertical connectivity is compromised. Potentially this site will improve with the present management plan over the next decade from 19/60 to 40/60.

Site B, partially beneath a canopy of mixed exotic and native trees, has effective water temperature control though leaf litter is sparse as the leaf fall is on to the flood plain rather then the stream. There is effective fish and macroinvertebrate habitat though the limited flooding history of the stream suggests that it is not a favourable spawning area. Longitudinal connectivity is maintained with upper and lower reaches. Some vertical connectivity occurs at the upper part of the reach where there is leaf fall. The potential for this site with strategic management of the north bank would see it progress from 34/60 to 56/60, and become a most pleasant recreation area.

The effects of past pastoral farming are seen particularly at site C where the stream banks have slumped and are severely damaged, no riparian cover exists beyond two gorse bushes, weeds are prolific, and excessive algal and macrophyte growth covers the stream. Though redfin bully and koura were found in very small numbers, the habitat is poor with no leaf litter to support macroinvertebrates. There were no current satisfactory riparian activity parameters. This site has the greatest potential for restoration. The uphill proximity of native shrubs and trees with seeding potential, supplemented by appropriate planting, should ensure an improvement in riparian activity from 10/60 to 53/60 over the next decade.

The current riparian activity at site D was moderate with tall gorse on the south bank and a high bank on part of the northeast bank. The stream bank had undercuts and stones making it a suitable habitat for macroinvertebrates and fish (galaxiids and bullies). However, there was a dearth of leaf litter and wood debris. Temperature control was a concern with moderate macrophyte growth over the summer. Potentially this site will benefit from stream bank planting with grasses and trees with the activity score expected to rise from 28/60 to 51/60.

The current riparian activity at site E evaluated as highly active apart from its capacity to control downstream flooding. The canopy of native trees has effective leaf fall and the stream banks are suitable for spawning. As a habitat for macronvertebrates and fish, it is very suitable. Temperature control was noted to be only moderate as the stream passed through open country before entering the bush. Restoration of the headwaters and establishment of a riparian zone in the valley would ensure that this was managed. The activity score would rise from 44/60 to 51/60.

The recreation and aesthetics functions provided by streams follow the restoration/ rehabilitation of their ecosystems. The re-establishment of longitudinal, lateral and vertical connectivity to the streams through riparian management is fundamental to restoration (Parkyn *et al*, 2003; Boulton, 2007; Jansson *et al*, 2007; Lake *et al*. 2007).

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# Chapter 4
# General Discussion

The future management of Whareroa Farm will be determined by the debate between the desire to allow forest regeneration and the desire to operate a viable farm unit in conjunction with Queen Elizabeth Park. All parties appear to be agreed, however, that the catchment in the steep hill country should not be further subjected to animal erosion and that its retirement from active farming is appropriate.

These studies established through the SEV and RMC processes that there was moderate to severe degradation of the stream network traversing the farm. They also established that there was considerable potential for recovery of stream health in conjunction with best practicable management (Rowe *et al,* 2003). The documentation of the current situation in the streams provides a basis for future stream recovery plans.

The ecological health of streams is a combination of their ecosystem structure and function. The studies found that both were markedly affected by the land-use changes of the last century perpetuated by current farm practices. Macroinvertebrate and fish communities were affected in all areas, with low MCI, QMCI and Fish IBI across the streams. These ecological indicators highlight that the reduced water quality and poor habitat provision in the streams are the direct cause of the poor representation of fauna, but also indicate that environmental improvement could, or should, improve this.

The lack of riparian zones was a major feature of the degradation of the Whareroa Stream network. The one small area of bush on the Ramaroa Stream was insufficient to atone for the lack of suitable fauna habitats. A positive programme of riparian fencing and riparian revegetation from the headwaters would improve the stream health. With increased stream protection from the riparian zone, temperature fluctuations, macrophyte excesses and increased turbidity would be moderated allowing increased numbers of aquatic insects and fewer gastropods and amphipods to occupy the streams. In-stream wood debris and organic matter input in turn would encourage more galaxiids and bullies to occupy the streams.

The comprehensive SEV process clearly showed the cumulative effects of stream degradation with the marked deterioration of ecological function at the downstream sites. The serious loss of ecological value in the site C stream was associated with the almost complete loss of any riparian zone to weeds, gorse, slumping banks and bank erosion from cattle entering the stream. The site C stream lies in a steep valley ill suited to farming but capable of forest restoration.

Though the two sites in Queen Elizabeth Park are effectively 'transit' areas, they are also potential habitats for galaxiids, bullies and eels. However, the habitat function at site A was not sustained in the late summer with collapse of the algae and macrophytes that occupied the stream and no EPT taxa, galaxiids or bullies were found. The long-term improvement of the catchment together with the riparian management of the lower reaches could be expected to reverse much of this ecological stress by moderating the deposition of sediment, excess nutrients from farm run-off and temperature fluctuations.

Of particular value to the assessment of the potential of the Whareroa Farm was the RMC-P where, given best practicable management of the farm, there is a predicted return to stream health. The unanswered questions in these studies are how much riparian protection is needed and how long will it be before any positive results can be discerned. The SEV and RMC provide monitoring measures for Regional Council managers as restoration proceeds.

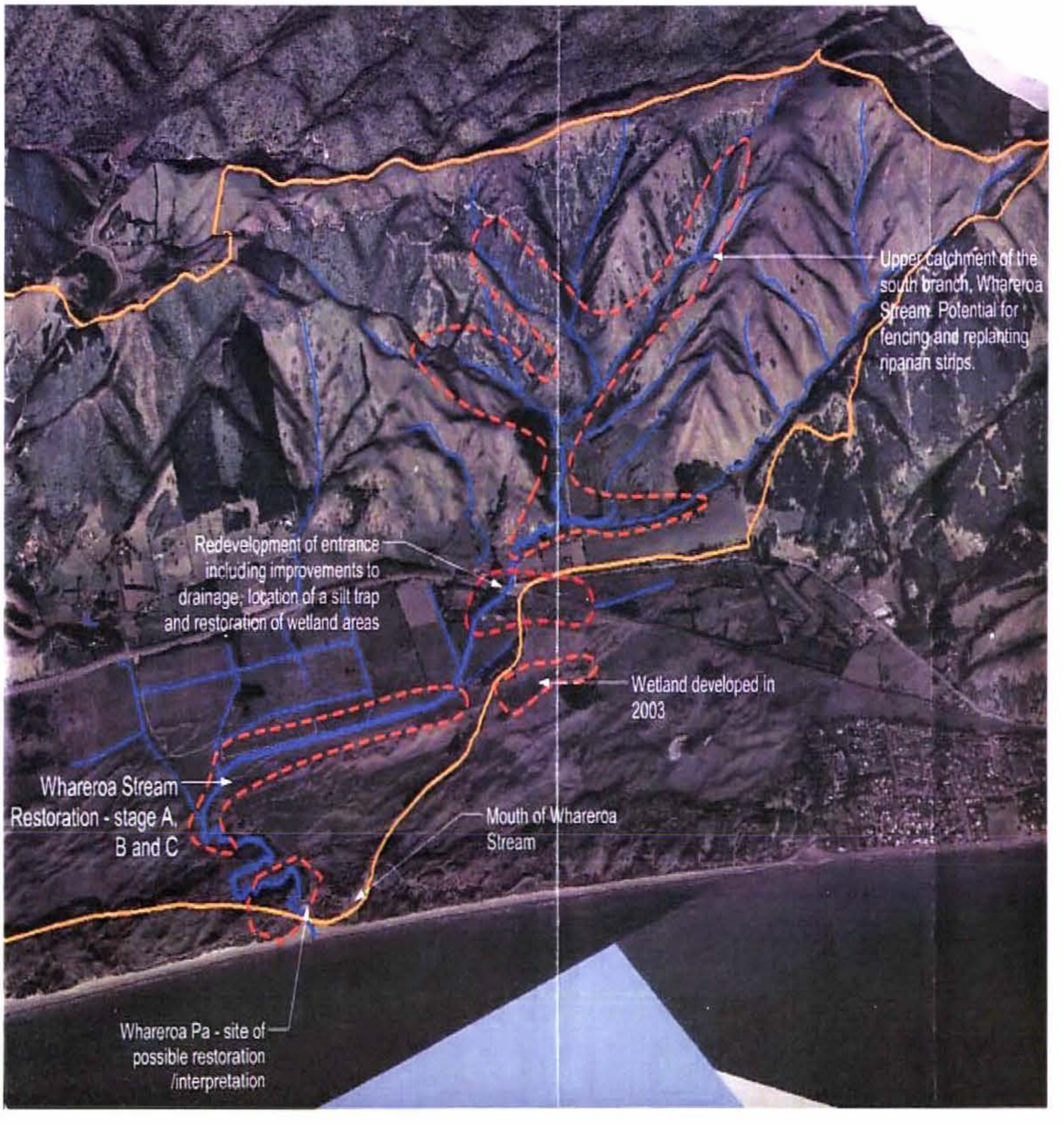
Successful stream and river restoration has frequently been poorly monitored. Woolsey *et al.* (2007) have drawn attention to the trial and error nature of many of the projects and have proposed an algorithm with defined objectives, goals and restoration measures as a more systematic approach to restoration success. The 'holy grail' is to restore a landscape to a pre-human condition for many projects. However, after a century of changes of land-use to agriculture as with Whareroa Farm, this is unachievable.

The proposed strategy to assess stream restoration success (Woolsey, 2007) commences with defining the project objectives, including the sustainability of the proposed restoration (social, environmental and economic). This is followed by development of indicators to assess the restoration success. These include ecological and functional indicators reflecting longitudinal, lateral and vertical connectivity. The SEV and RMC assessments used in the above studies would provide this assessment.

Practical management guidelines for weed management, stock access, vegetation management and channel design have been proposed by Rutherfurd *et al* (2001) with particular reference to the situation in South Australia. In general, they are applicable to New Zealand streams also.

A community model for community involvement in restoration projects was used successfully in 1998 in the Avoca Valley Stream, Canterbury. The guidelines for this restoration provide a New Zealand model that would be suitable for the Whareroa Farm (Lucas, 1998). Map 4 shows a 2006 proposal for riparian fencing and catchment retirement.

**Map 4.** 2006 Proposal for Whareroa Farm and Queen Elizabeth Park. (Greater Wellington Regional Council and DOC.)



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## Index of Appendices

## Appendix 1. Stream Ecological Valuation Algorithms.

(after Rowe et al, 2006)

### 1. Hydraulic functions:

- ***Natural flow regime*** (NFR): Channel type was assessed visually and the extent of any modifications, including channelisation, calculated proportionally.

  The variables measured were:

  **Vbed** This was a visual estimate of the extent of any modification to the stream channel that may have affected the flow regime. The length of affected channel was assessed as a proportion of the length of the stream reach, weighted and summed.

  Scoring:

| Channel type | Proportion of channel affected (P) | Weighting (W) | Score (WxP) |
|---|---|---|---|
| Natural channel bed with no modification | | 1.0 | |
| Natural channel bed but with some unnatural fine sediment loading | | 0.7 | |
| Channelised with some or no modification (eg gabions) | | 0.5 | |
| Channelised with total modification (eg concrete lining) | | 0.1 | |

$V_{bed} = \sum (W x P)$

**Verosn** The proportion of any erosion to the banks from flooding was estimated. Erosion from cattle or other non-natural causes was excluded.

Scoring:

| | |
|---|---|
| Proportion <5% | Verosn = 1.0 |
| Proportion 6-30% | Verosn = 0.7 |
| Proportion 31-60% | Verosn =0.2 |
| Proportion 61-100% | Verosn = 0.1 |

**Vimper** The impact of any imperviousness upstream of the reach, such as culverting, was assessed to be a proportion of the surface water flow impediment from the catchment. The impact of imperviousness depends on any flood flow control measures upstream of the reach reduces the effects of imperviousness and where there are no impervious surfaces, Vimper = 1.

Scoring:

| Proportion of the catchment that is impervious | Much control | Some control | No control |
|---|---|---|---|
| <10% | 0.9 | 0.8 | 0.7 |
| 10-25% | 0.5 | 0.4 | 0.3 |
| >25% | 0.3 | 0.2 | 0.1 |

**Algorithm for scoring the Natural Flow Regime (NFR) Function.**

$$NFR = \frac{(Vbed + Verosn)}{2} \times Vimper$$

- ***Connectivity to flood-plain*** (CFP): Connectivity with flood-plains is an essential foil for diffusing and delaying flood events, particularly in the lower reaches of a stream. They further provide spawning grounds for several native freshwater fish. The variables measured were:

  **Vfpwidth** The mean width of the floodplain (A), excluding the wetted width, was measured at each of the 10 transects of each stream. The mean wetted channel width was also measured across each of the 10 transects. The 'I' value was determined where I=A/B.

  **Scoring:**

| I value | >/= 4 | 2-4 | 1-2 | 1 |
|---|---|---|---|---|
| Vfpwidth | 1.0 | 0.7 | 0.4 | 0 |

**Vfreq** Flood frequency estimations for the Wharcroa Stream catchment was obtained from the Wellington Regional Council Ranger based on observed bank-full height and proportionally applied to the network of streams from the catchment.

Scoring:

| Estimated frequency of flood flows that inundate the flood-plain per year | Rare (<1/yr) | Occasional (1-2/yr) | Often (3-5/yr) | Frequent (>5/yr) |
|---|---|---|---|---|
| Value of Vfreq | 0.10 | 0.40 | 0.80 | 1.0 |

**Algorithm for scoring Connectivity to Floodplain (CFP) Function**

$$CFP = \frac{Vfpwidth + Vfreq}{2}$$

- ***Connectivity for species migrations*** (CSM): Natural and artificial barriers within the reach were surveyed for their effects on the annual migrations of migration of diadromous fish and macro-invertebrates such as shrimps (*Paratya curvirositis*). The connectivity between upstream freshwater habitats and the sea determines the spawning success or disappearance of a species.

The variables measured were:

**Vbarr** The number and type of barrier were noted during visual inspection of the reach to gauge likely effects on migratory species.

Scoring:

| | |
|---|---|
| No barrier(s) | Vbarr = 1.0 |
| Partial barrier(s) | Vbarr = 0.3 |
| Total barrier | Vbarr = 0.0 |

**Vcatch** The proportion of total catchment ($P_c$) affected was calculated, indicating the overall ecological importance of the barriers.

Scoring: $V_{catch} = P_c$

**Algorithm for scoring Connectivity for Species Migrations (CSM) Function** **CSM = Vbarr x Vcatch**

- ***Connectivity to groundwater (CGW):*** The connectivity with the hyporrheic zone is a great importance for the biochemical processing of nutrients and contaminants.

  The variable measured was:

  **$V_{bed}$** The streambed was assessed visually for changes associated with any modifications to the channel and scored as for the NFR function.

  Scoring: $V_{bed} = \sum (W x P)$

| **Algorithm for scoring the Connectivity to Groundwater (CGW) Function** |
|---|
| **CGW = $V_{bed}$** |

## 2. Biogeochemical functions:

- ***Water temperature control:*** Water temperature control is pivotal in ecological performance of streams. Shade, water depth, water velocity, exposure to solar radiation and the variations in ambient air temperatures all contribute to the overall ecological processes of the streams.

  The variables measured were:

  **$V_{shade}$** The proportion of stream shaded by vegetation and/or high banks was estimated by evaluating the proportion (A) of open sky present over 10 transects. The assessment assumed midsummer conditions with the sun directly overhead.

  Scoring: $V_{shade} = A/10$

  **$V_{depth}$** The depth (Z) was measured across 10 transects at distances of 0, 12, 50, 75 and 100% of the channel. The mean depth ($Z_m$) was calculated.

  Scoring:

| $Z_m$ | $V_{depth}$ |
|---|---|
| 0.05 | 0.5 |
| 0.06-0.10 | 0.6 |
| 0.11-0.20 | 0.7 |
| 0.21-0.40 | 0.8 |
| >0.41 | 1.0 |

**Vveloc** The velocity was measured as the change in depth at each of the same equidistant points across the 10 transects. The direct readings were used to calculate the velocity and the mean (Sm) was calculated.

Velocity (m/sec) = $\sqrt{2gh}$ (g = gravity = 9.8; h = height of change in metres)

Scoring:

| Sm | Vveloc |
|---|---|
| 0.05 | 1.0 |
| 0.06-0.10 | 0.9 |
| 0.11-0.20 | 0.8 |
| 0.21-0.40 | 0.7 |
| >0.41 | 0.6 |

**Vlength** The length (L) of the stream reach was measured.

Scoring:

| L (m) | Vlength |
|---|---|
| >300m | 1.0 |
| 101-300 | 0.9 |
| 51-100 | 0.8 |
| 0-50 | 0.4 |

**Algorithm for scoring Water Temperature Control (WTC) Function**

$$WTC = Vshade \times \frac{(Vdepth + Vveloc + Vlength)}{3}$$

- ***Dissolved oxygen maintenance*** (DOM): The amount of dissolved oxygen in water determines the organisms that can live in that environment. Where the levels are low, only tolerant biota can survive. Oxygen is made available from photosynthesis and from diffusion of atmospheric oxygen, and is improved in streams with some turbulence as the surface area of the water is increased. Reducing factors include abundant plant growth as they absorb oxygen at night, decomposition of organic matter, and nitrification of ammonia.

  The variable measured was:

  **Vdod** The dissolved oxygen demand (DOD) was calculated visually across 10 equidistant transects with regard to the presence or absence of anaerobic sediment, bubbling from the sediment, sulphide odour, sewage fungus, surface scum, and amount of macrophyte biomass. The mean of scores was derived.

**Scoring:**

If there were no oxygen reducing processes, then $V_{dod}$ = DOD =1

If $V_{dod}$ = >1, then the correction factor $C = (S/Z)^{0.25}$ was applied (S = mean velocity, Z = mean depth), and $V_{dod}$ = DOD x C.

If $V_{dod}$ >1, $V_{dod}$ set at 1.

If <1, then that is $V_{dod}$.

| Status of stream substrate | Indicators of oxygen reducing processes | Score (DOD) |
|---|---|---|
| Poor | -much black anaerobic sediment<br>-extensive sediment bubbling when disturbed<br>-sulphide odour when disturbed<br>-surface scum present<br>-abundant sewage fungus | 0.25 |
| Marginal | -small patches of anaerobic sediment present<br>-some sediment bubbling and sulphide odour when disturbed<br>-some sewage fungus may be present<br>-dense macrophyte biomass | 0.50 |
| Sub-optimal | -no anaerobic sediment<br>-no sediment bubbling or sulphide present<br>-moderate macrophyte biomass | 0.75 |
| Optimal | No anaerobic sediment<br>-no bubbling or odours<br>-Little or no macrophyte biomass | 1.0 |

**Algorithm for scoring Dissolved Oxygen Maintenance (DOM) Function**

**DOM = $V_{dod}$**

- ***Organic matter input*** (OMI): The amount of organic matter put into a stream is an indicator of its production potential. The major part of this is leaf fall, which can be measured by assessing the total amount of overhead cover provided by the canopy above the stream. As deciduous trees have leaf fall only in autumn and winter, the total amount of summer vegetation needs to be reduced by the proportion that is deciduous.

  The variables measured were:

**Vcanop** Scoring:

The proportion of canopy cover directly overhead was estimated

**Vdecid** Scoring:

The proportion of canopy cover over the reach that is deciduous

**Algorithm for scoring Organic Matter Input (OMI) Function**

$$OMI = Vcanop - \frac{(Vcanop \times Vdecid)}{2}$$

- ***In-stream particle retention*** (IPR): Leaf fall is only useful if the leaves are retained within the stream long enough for aquatic invertebrates, microbes and fungi to process them. Retention depends on the length of the reach and its flow characteristics, particularly velocity and hindrances to flow.

The variables measured were:

**Vtrans** Leaf analogues were used to measure the leaf retention within the reach. Ten "leaves" were dropped at the upper end of the 50m reach and any stoppage recorded for distance travelled. Another 10 "leaves" were dropped into the reach at 25m from the end and similar measurements made. The geometric mean (dr) distance that the leaves travelled was calculated and assessed relative to the ARC reference sites value of df = 4.8. D was calculated as dr/df.

**Scoring:**

| D (dr/df) | Vtrans |
|---|---|
| <1 | 1.0 |
| 1-2 | 0.7 |
| 3-4 | 0.4 |
| >44 | 0.1 |

**Vretain** The structures stopping the leaf analogues (eg cobbles, vegetation, roots, periphyton) were documented, and the proportion of each structure estimated. The value of the weighting x proportion (WxP) was divided by 0.5, the mean value measured for the ARC reference sites.

**Scoring:**

| Structures retaining leaves | Boulders & cobbles | Large wood & tree roots | Rooted aquatic plants | Periphyton & leaf litter | Small wood | Bankside vegetation | Non-natural debris | Pools |
|---|---|---|---|---|---|---|---|---|
| Weighting (W) | 0.9 | 1.0 | 0.5 | 0.3 | 0.5 | 0.4 | 0.2 | 0.7 |
| Proportion of structures | | | | | | | | |
| W x P | | | | | | | | |

$V_{retain} = \sum (W P) / 0.5$

**Algorithm for scoring In-stream Particle Retention (IPR) Function**

**IPR = $V_{trans}$ x $V_{retain}$**

- ***Decontamination of pollutants*** (DOP): The type and extent of micro-organisms growing on suitable substrates within the stream reach provide the principal physico-chemical processes for decontamination of pollutants.

  The variable measured was:

  **$V_{surf}$** The principal substrates associated with micro-organisms that decontaminate chemicals and contaminants (eg leaf litter, periphyton, roots, wood) were visually assessed for type and proportion.

  The sum of the (W x P) values was divided by the ARC reference sites mean, 0.36.

  **Scoring:**

| Surface type | Weighting (W) | Proportional cover (P) | W X P |
|---|---|---|---|
| Leaf litter | 1.0 | | |
| Periphyton, submerged macrophytes | 1.0 | | |
| Wood, roots, plus emergent floating | 0.5 | | |
| Boulders | 0.4 | | |
| Gravel, cobble | 0.3 | | |
| Silt, bedrock | 0.2 | | |

$V_{surf} = \sum (W \times P) / 0.36$

| **Algorithm for scoring Decontamination of Pollutants (DOP) Function** |
|---|
| **DOP = $V_{surf}$** |

- ***Flood-plain particle retention*** (FPR): Out-of-channel particle retention plays a very important part in sustaining ecological values by retaining silt and vegetation loaded in floods and incorporating them in the riparian ecological system. The width of the flood plain and the type of vegetation will determine its effectiveness.

  The variables measured were:

  **$V_{fpwidth}$** See CFP function calculations

  **$V_{freq}$** See CFP function calculations

  **$V_{rough}$** The flood plain width, flood frequency and the nature of vegetation (short grass, long grass, shrubs or trees) on the flood plain were determined.

  **Scoring:**

| | Low (eg. bare or mown/grazed grass) | Moderate (eg. sedges & long grasses) | Moderate (eg. trees & thin understorey | High (eg flax, shrubs, thick understorey) |
|---|---|---|---|---|
| Weighting (W) | 0.1 | 0.7 | 0.4 | 1.0 |
| Proportion of bank covered (P) | | | | |
| P x W | | | | |

$V_{rough} = \sum (P \times W)$

| **Algorithm for scoring Flood particle Retention (FPR) Function** |
|---|
| **FPR = $\frac{(V_{fpwidth} + V_{rough} + V_{freq})}{2}$** |

**3. Habitat provision functions:**

- ***Fish spawning habitat*** (FSH): A key function of streams is the provision of spawning habitats for fish. Galaxiid species deposit eggs on stream banks at high water level among the roots of grasses and shrubs. Bullies deposit eggs on hard surfaces such as the undersides of rocks and in-stream wood.

The variables measured were:

**$V_{galspwn}$** The length of the near-flat (slope <10°) banks ($L_b$) that would be inundated by floods or high tides, and the total length of the reach ($L_s$), were measured.

$R = L_b/L_s$ was calculate

**Scoring:**

| R | $V_{galspwn}$ |
|---|---|
| >0.25 | 1.0 |
| 0.11-0.25 | 0.5 |
| 0.01-0.10 | 0.25 |
| 0 | 0 |

**$V_{galqual}$** The quality of the vegetation for galaxiid spawning was assessed.

**Scoring:**

| | $V_{galqual}$ |
|---|---|
| High | 1.0 |
| Med | 0.75 |
| Low | 0.25 |

**$V_{gobspwn}$** Each streambed was assessed for suitability as a habitat for spawning bullies across 10 transects. The overall proportions of suitable habitats were combined as (P) ie. large gravel to boulder substrate categories + large wood categories but not bedrock, sand or silt.

**Scoring:**

| P | $V_{gobspwn}$ |
|---|---|
| >10% | 1.0 |
| 5-10% | 0.8 |
| 2-4% | 0.2 |
| 2% | 0.1 |

**Algorithm for scoring Fish Spawning Habitat (FSH) Function**

$$FSH = \frac{(V_{galspwn} \times V_{galqual}) + V_{gobspwn}}{2}$$

- ***Habitat for aquatic fauna*** (HAF): The physical habitat for fish and invertebrates is created by interactions between many aspects of the physical functions within a stream. The ARC physical habitat assessment protocol was used to assess the five sites.

  The variables measured were:

  **$V_{physhab}$** The ARC physical habitat chart was completed. This included an assessment of the aquatic habitat appropriate for colonisation, aquatic habitat stability, hydrologic conditions within the stream, channel shade and effect of human activity on riparian vegetation integrity within 20m of the stream (see Appendix 2). The sum of the scores (H) produced a value out of 100, and this was compared to the relative ARC reference standard habitat score of 0.86

  **Scoring:** $V_{physhab} = H/0.86$

  **$V_{watqual}$** Water quality was assessed as a function of effective shading, and any impervious substrate, as these are important functions in water temperature control. The shade was assessed both over the reach ($V_{shade}$) and upstream (S).

  **Scoring:**

| Extent of stream above the reach being assessed that is shade: | S |
|---|---|
| Well shaded (ie. >50% of entire stream above reach is shaded) | 1.0 |
| Partially shaded (ie. <50% of stream above site is forested) | 0.5 |
| Minimal shade (eg. mainly pasture, but some riparian cover present) | 0.2 |
| No shade (mainly open pasture) | 0.1 |

$$V_{watqual} = DOM \times \frac{V_{shade} + S}{2}$$

  **$V_{imper}$** The amount of impervious cover was measured and scored as in NFR function

**Algorithm for scoring Habitat for Aquatic Fauna (HAF) Function**

$$HAF = \frac{V_{physhab} + (V_{watqual} + V_{imper})/2}{2}$$

**4. Biodiversity functions:**

- ***Riparian vegetation intact*** (RVI): The riparian zone plays a major role in maintaining stream ecological health. It acts as a filter to surface and groundwater entering the stream, provides overhead cover, provides wood debris and leaf litter, and maintains aquatic insects. Stream water supports the riparian plants and provides a haven for the larvae of terrestrial and aquatic insects. The land-water interface and interactions are key to ecological health.

  The variables measured were:

  **Vripcond** The current contribution of the riparian vegetation to the stream ecology was assessed and scored according to the table.

  **Scoring:**

| Status of riparian vegetation | Score (Vripcond) |
|---|---|
| -mature indigenous vegetation, regeneration<br>-diverse canopy and under-storey | 1.0 |
| -intact mature canopy but damaged understorey | 0.7 |
| -regenerating bush (eg. manuka scrub)<br>-low diversity, early stage in climax<br>-protected | 0.6 |
| -as for above but unprotected (eg. cattle grazing understorey | 0.3 |
| -occasional native trees present, non native trees | 0.1 |

  **Vripconn** The proportion of the stream channel where there was clear connection between the riparian vegetation and stream was determined.

  **Vripar** The proportion of the riparian zone, 10m each side of the stream, covered in trees or bush was determined.

**Algorithm for Riparian Vegetation Intact (RVI) Function**

$$RVI = \frac{Vripcond + Vripconn + Vripar}{3}$$

- ***Invertebrate fauna intact*** (IFI): An intact invertebrate fauna is fundamental to the conversion of primary production into secondary production in a stream and hence the productivity of fish. The ecological integrity of a stream requires an intact fauna.

The variables measured were:

**Vmci** This was calculated from the MCI index of the sample invertebrates and then expressed as a proportion of the mean reference MCI (**Stark, 1985**).

**Scoring:** $MCI_{adj} = MCI/MCI_{ref}$

| $MCI_{adj}$ | $V_{mci}$ |
|---|---|
| >100 | 1.0 |
| 90-100 | 0.7 |
| 80-90 | 0.3 |
| 70-80 | 0.1 |
| <40-70 | 0 |

**Vept** The EPT index was calculated for the samples, and then expressed in relation to the EPT value for the references sites.

**Scoring:** $EPT_{adj} = EPT/EPT_{ref}$

$V_{ept} = EPT_{adj}$

**Algorithm for scoring Invertebrate Fauna Intact (IFI) Function**

$$IFI = \frac{V_{mci} + V_{ept}}{2}$$

- ***Fish fauna intact*** (FFI): If the food web is disrupted the habitat for fish may be apparent in reduced or absent populations in spite of high quality water. Fish populations are a major component of fauna in streams, (Joy& Death, 2005)

The variable measured was:

**Vfish** this was calculated from the IBI that was derived from fish trap and electro-fishing sampling (**Joy, 2004**).

**Scoring:** $V_{fish} = IBI/60$

**Algorithm for scoring Fish Fauna Intact (FFI) Function**

$$FFI = V_{fish}$$

**Appendix 2.** **Stream Ecological Study Field sheet.**

(developed from SEV (Rowe et al, 2006) & SHMAK Kit)

# HYDRAULIC

## [1] Natural Flow Regime:

**Extent of channel modification**

| *Channel type* | *Proportion of channel affected* |
|---|---|
| Natural channel w. no modification | |
| Natural channel some unnat. Fine sed loading | |
| Channelised w. some/no modification | |

**Proportion of stream length affected by bank erosion from flood flows (not cattle):**
(circle one)

<5% 6-30% 31-60% 61-100%

## [2] Connectivity to flood plain:

**[A] Flood plain width:**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 |

**[B] Wetted channel width:**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 |

## [3] Connectivity for fish migration:

**Barriers to migration (%)**

| | |
|---|---|
| No barrier | |
| Partial barrier | |
| Total barrier | |

**Total catchment area not affected by barriers (%)** [ ]

## [4] Connectivity with groundwater maintained:

(use SEV substrate assessment)

## BIOGEOCHEMICAL:

### [1] Water temperature control:

**Proportion of open sky at 10 transects**

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
| 6 | 7 | 8 | 9 | 10 |

**Depth at 5 points for 10 Cross-sections:**

| | 0% | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

**Velocity at 5 points for 10 cross sections:**

| | 0% | 25% | 50% | 75% | 100% |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |

**Length of stream reach:**

| |
|---|
| |

### [2] Dissolved oxygen maintenance:

| | |
|---|---|
| Lots of black anaerobic sediment, bubbling when disturbed, sulphide odour, surface scum & sewage fungus | |
| Small patches of anaerobic sediment, some bubbling & odour, lots of plant biomass, maybe some sewage fungus. | |
| No anaerobic sediment, no bubbling or odour, moderate biomass | |
| No anaerobic sediment, co bubbling or odour, little or no biomass | |

## [3] Organic matter input:

**% of stream with overhead vegetation:** [ ]

**% deciduous:** [ ]

## [4] Instream particle retention:

**Coarse particle retention:**
Measure distance leaf analogue particles travel: (2 replicates, 0m & 25m)

| *Replicate 1 (at top of study zone)* | *Replicate 2 (25m down study zone)* |
|---|---|
| 1 | 1 |
| 2 | 2 |
| 3 | 3 |
| 4 | 4 |
| 5 | 5 |
| 6 | 6 |
| 7 | 7 |
| 8 | 8 |
| 9 | 9 |
| 10 | 10 |

**Structures retaining leaf particles:**

| *Structure* | *No leaf analogues trapped* |
|---|---|
| Boulders/cobbles | |
| Large wood/tree roots | |
| Rooted aquatic plants | |
| Periphyton & leaf litter | |
| Small wood | |
| Bankside vegetation | |
| Non-natural debris | |

## [5] Decontamination of pollutants:

| *Stream-bed surface type* | *Proportion* |
|---|---|
| Leaf litter | |
| Periphyton, submerged macrophytes | |
| Wood, roots + emergent/ floating | |
| Gravel, cobble | |
| Silt, bedrock | |

**Periphyton** (SHMAK identification)

| | *Colour* | *Proportion* |
|---|---|---|
| *Thin mat/film <0.5mm thick* | Green | |
| | Light brown | |
| | Dark brown | |
| *Medium mat/film 0.5-0.8mm* | Green | |
| | Light brown | |
| | Dark brown | |
| *Thick mat >3mm thick* | Green | |
| | Light brown | |
| | Dark brown | |
| *Filaments <2cm long* | Green | |
| | Reddish/brown | |
| *Filaments >2cm long* | Green | |
| | Reddish/brown | |

**Macrophyte species & % cover**

| *Species* | *% cover* | *Species* | *% cover* |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

## [6] Floodplain particle retention:

**Floodplain vegetation cover**

| *Vegetation type* | *Proportion* |
|---|---|
| Bare/ short areas, grazed/ mown | |
| Sedges + long grasses | |
| Flax, shrubs or dense understorey | |
| Trees with thin understorey | |

## HABITAT

### [1] Fish spawning habitat:

**Measure length of low-gradient bank at flood level for galaxid spawning:** [ ]

**Habitat quality for galaxids;**
(vegetation suitable for egg deposition) high medium low

**Habitat quality for bullies**
(large permanent structures in the channel for egg deposition) high medium low

### [2] Habitat for aquatic fauna:

(complete chart)

**Upstream shading:**

| *Extent of stream above the reach being assessed that is shaded* | |
|---|---|
| Well-shaded (ie >50%of entire stream above site is forested) | |
| Partially shaded (ie. <50% stream above site forested) | |
| Minimal shade (eg mainly pasture, but some riparian cover present) | |
| No shade (mostly open pasture) | |

**Turbidity/water clarity measurements;** (SHMAK chart)

| *Clarity tube reading* | |
|---|---|
| Clear to bottom (Visually clear) | |
| 70 – 90 cm (slightly turbid) | |
| 55 – 69cm (moderately turbid) | |
| 35 – 54cm very turbid) | |
| <35cm (extremely turbid) | |

## BIOTIC

### [1] Fish Fauna Intact:

- Electrofish
- Identification
- Determine IBI (Index of Biotic Integrity) for the stream (Joy & Death 2005)

### [2] Invertebrate fauna intact:

- Carry out 5 surber samples for invertebrates (commencing at bottom of the reach).
- Identify the invertebrates (separate chart)
- Calculate MCI index for stream
- Assess aquatic biodiversity (actual vs predicted)

## RIPARIAN ASSESSMENT

**[1] Status of riparian vegetation to 10m from stream edge**

| | |
|---|---|
| Mature indigenous vegetation, regeneration<br>Diverse canopy and under-storey | |
| Intact mature canopy but damaged under-storey | |
| Regenerating bush, low diversity, early stage in climax<br>Protected | |
| As above but unprotected (eg cattle grazing under-storey) | |
| Occasional native trees present, non-native trees | |

**List of dominant riparian vegetation:**

(Separate chart)

## [2] Riparian management classification *(After Quinn 2003)*

| | Physical attribute | Scoring | Site |
|---|---|---|---|
| | | | |
| **Catchment** | Source of flow | 1 = lake or lowland<br>2 = hill<br>3 = mountain | |
| | Dominant baserock geology index | 1 = soft sedimentary<br>2 = alluvium & sand<br>3 = miscellaneous<br>4 = volcanic<br>5 = hard sedimentary | |
| | Catchment average. slope (°) | | |
| | Upstream annual rainfall (mm) | | |
| | Landcover index | 1= bare<br>2 = urban<br>3 = pasture<br>4 = tussock<br>5 = exotic forest<br>6 = scrub<br>7 = indigenous forest | |
| | | | |
| **Valley segment** | Riparian landuse | Cattle; conservation; crop; dairy; forestry; horticulture; sheep; urban. | |
| | Channel shape | 1 = channelised<br>2 = straight<br>3 = meandering<br>4 = sinuous | |
| | Mean annual local air temperature | | |
| | Reach elevation (m) | Above SL | |
| | Domain land drainage class | 1 = very poor<br>2 = poor<br>3 = impeded<br>4 = moderate<br>5 = good | |
| | | | |
| **Reach** | Water width | Wetted stream width (m) | |
| | Flood plain width | Width of flood plain (m) | |
| | Wet/dry index | 0 = dry channel<br>1 = water present | |
| | Channel width (m) | | |
| | Substrate composition | Bedrock, boulder, cobble, gravel, sand, silt, clay | |
| | Vegetation height | Ave vegetation height (m) | |
| | Bank height | Ave bank height (m) | |
| | Shade ratio | Bank + vegetation height/channel width | |

| | | | |
|---|---|---|---|
| | Periphyton categories | 0 = none<br>1 = slippery<br>2 = obvious<br>3 = abundant<br>4 = excessive | |
| | Macrophyte species & % cover | Species present, % total bed covered | |
| | Woody debris index | 0 = absent<br>1 = sparse<br>2 = common<br>3 = abundant | |
| | Stock access index | 0 = no access<br>1 = one bank<br>2 = both banks | |
| | Stock bank damage index | 0 = none<br>1 = minor<br>2 = moderate<br>3 = extensive | |
| | Streambank stability | % bank stable, undercut or slumped | |
| | Dominant riparian vegetation cover | 0 = bare ground<br>1 = grass<br>2 = wetland<br>3 = low shrub<br>4 = high shrub<br>5 = deciduous<br>6 = willows<br>7 = conifers<br>8 = eucalyptus<br>9 = native | |
| | Stock fencing stream index | 0 = none<br>1 = one side<br>2 = both sides | |
| | Stock damage classes | 0 = none<br>1 = minor<br>2 = moderate<br>3 = extensive | |
| | Riparian fencing | % each bank fenced<br>&<br>distance from bank to fence | |
| | Fencing type index | 0 = none<br>1 = electric one wire<br>2 = electric 2 wires<br>3 = post & batten/ electric 5-7 wire/ deer fence | |

## Riparian vegetation (10m) and bank cover

| Site/Date | Species: Weeds | Species: Natives | Species: Exotics – non-deciduous | Species: Exotic – Deciduous |
|---|---|---|---|---|
| Site:<br><br>Date: | | | | |

## Vfish (Electrofishing)

| **Site:** | **Date:** | **Comments:** include water conditions, riparian, bank cover, |
|---|---|---|
| **GALAXIIDS:**<br>**Inanga** | | |
| **Banded kokopu** | | |
| **Giant kokopu** | | |
| **Koara** | | |
| **Short jawed kokopu** | | |
| | | |
| **BULLIES:**<br>**Redfin bully** | | |
| **Common Bully** | | |
| **Giant bully** | | |
| | | |
| **Torrentfish** | | |
| **EELS:**<br>**Short finned** | | |
| **Long finned** | | |
| | | |
| **CRUSTACEA:**<br>**Shrimps**<br>***(Paratya)*** | | |
| **Koura**<br>***(Paranephrops)*** | | |

**Appendix 3. ARC data sheet for assessing physical habitat for aquatic fauna.**

**HABITAT FOR AQUATIC FAUNA**

| | Optimal | Suboptimal | Marginal | Poor |
|---|---|---|---|---|
| Aquatic Habitat Abundance | >50% of channel favourable for epifaunal colonisation and fish cover; includes woody debris, undercut banks, root mats, rooted aquatic vegetation, cobble or other stable habitat. Also includes microphyte dominated streams. | 30-50% of channel contains stable habitat. | 10-30% of channel contains stable habitat. | <10% of channel contains stable habitat<br><br>Note: Algae is not stable habitat |
| | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| Aquatic Habitat Diversity | Wide variety of stable aquatic habitat types present including: woody debris, riffles, undercut banks, root mats, rooted aquatic vegetation, cobble or other stable habitat. | Moderate variety of habitat types; 3-4 habitats present including woody debris | Habitat diversity limited to 1-2 types; woody debris rare or may be smothered by sediment | Stable habitats lacking or limited to macrophytes (a few microphyte species scores lower then several) |
| | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| Hydrologic Hetero-geneity | Mixture of hydrologic conditions i.e pool, riffle, run, chute, waterfalls; variety of pool sizes and depths. | Moderate variety of hydrologic conditions, deep and shallow pools present (pool size relative to size of stream) | Limited variety of hydrologic conditions; deep pools absent (pool size relative to size of stream) | Uniform hydrologic conditions; uniform depth and velocity, pools absent (includes uniformly deep streams) |
| | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| | | | | |
| Channel shade | >80% of water surface shaded. Full canopy. | 60-80% of water surface shaded; mostly shaded with open patches | 20-60% of water surface shaded; mostly open with shaded patches | <20% of water surface shaded. Fully open, lack of canopy cover. |
| | 20 19 18 17 16 | 15 14 13 12 11 | 10 9 8 7 6 | 5 4 3 2 1 0 |
| Riparian vegetation integrity | No direct human activity in the last 30 years; mature native tree canopy and intact native understory. | Minimal human activity; mature native tree canopy or native scrub; understory shows some impact (e g. weeds, feral animal grazing) | Extensive human activity affecting canopy and understory; trees exotic; understory native or exotic | Extensive human activity; little or no canopy; managed vegetation (grazing/mowed); permanent structures may be present (buildings/ roads etc) |
| Left bank | 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |
| Right bank | 10 9 | 8 7 6 | 5 4 3 | 2 1 0 |

# Appendix 4. MCI Scores (Stark, 1999)

**Odonata**
- *Aeschna* ... 5
- *Antipodochlora* ... 6
- *Austrolestes* ... 6
- *Hemicordulia* ... 5
- *Xanthocnemis* ... 5
- *Procordulia* ... 6

**Ephemeroptera**
- *Ameletopsis* ... 10
- *Arachnocolus* ... 8
- *Atalophlebioides* ... 9
- *Austroclima* ... 9
- *Coloburiscus* ... 9
- *Deleatidium* ... 8
- *Ichthybotus* ... 8
- *Isothraulus* ... 8
- *Mauiulus* ... 5
- *Neozephlebia* ... 7
- *Nesameletus* ... 9
- *Oniscigaster* ... 10
- *Rallidens* ... 9
- *Siphlaenigma* ... 9
- *Zephlebia* ... 7

**Plecoptera**
- *Acroperla* ... 5
- *Austroperla* ... 9
- *Cristaperla* ... 8
- *Halticoperla* ... 8
- *Megaleptoperla* ... 9
- *Spaniocerca* ... 8
- *Spaniocercoides* ... 8
- *Stenoperla* ... 10
- *Taraperla* ... 7
- *Zelandobius* ... 5
- *Zelandoperla* ... 10

**Hemiptera**
- *Diaprepocoris* ... 5
- *Microvelia* ... 5
- *Sigara* ... 5

**Megaloptera**
- *Archichauliodes* ... 7

**Trichoptera**
- *Aoteapsyche* ... 4
- *Beraeoptera* ... 8
- *Confluens* ... 5
- *Costachorema* ... 7
- *Edpercivalia* ... 9
- Ecnomidae ... 8
- *Helicopsyche* ... 10
- *Hudsonema* ... 6
- *Hydrobiosella* ... 9
- *Hydrochorema* ... 9
- *Kokiria* ... 9
- *Neurochorema* ... 6
- Oeconesidae ... 9
- *Olinga* ... 9
- *Orthopsyche* ... 9
- *Oxyethira* ... 2
- *Paroxyethira* ... 2
- *Philorheithrus* ... 8
- *Plectrocnemia* ... 8
- *Polyplectropus* ... 8
- *Psilochorema* ... 8
- *Pycnocentrella* ... 9
- *Pycnocentria* ... 7
- *Pycnocentrodes* ... 5
- *Rakiura* ... 10
- *Tiphobiosis* ... 6
- *Triplectides* ... 5
- *Zelolessica* ... 10

**Lepidoptera**
- *Hygraula* ... 4

**Mecoptera**
- *Nannochorista* ... 7

**Coleoptera**
- *Antiporus* ... 5
- *Berosus* ... 5
- Dytiscidae ... 5
- Elmidae ... 6
- Hydraenidae ... 8
- Hydrophilidae ... 5
- *Liodessus* ... 5
- Ptilodactylidae ... 8
- *Rhantus* ... 5
- Scirtidae ... 8
- Staphylinidae ... 5

**Diptera**
- *Aphrophila* ... 5
- *Austrosimulium* ... 3
- *Calopsectra* ... 4
- Ceratopogonidae ... 3
- *Chironomus* ... 1
- *Cryptochironomus* ... 3
- *Culex* ... 3
- Empididae ... 3
- Ephydridae ... 4
- Eriopterini ... 9
- *Harrisius* ... 6
- Hexatomini ... 5
- *Limonia* ... 6
- *Lobodiamesa* ... 5
- *Maoridiamesa* ... 3
- *Mischoderus* ... 4
- *Molophilus* ... 5
- Muscidae ... 3
- *Neocurupira* ... 7
- *Nothodixa* ... 5
- Orthocladiinae ... 2
- *Parochlus* ... 8
- *Paradixa* ... 4
- *Paralimnophila* ... 6
- *Paucispinigera* ... 6
- *Peritheates* ... 7
- Podonominae ... 8
- *Polypedilum* ... 3
- Psychodidae ... 1
- Sciomyzidae ... 3
- Stratiomyidae ... 5
- Syrphidae ... 1
- Tabanidae ... 3
- Tanypodinae ... 5
- Tanytarsini ... 3
- *Tanytarsus* ... 3
- *Zelandotipula* ... 6

**Collembola** ... 6

**Crustacea**
- Amphipoda ... 5
- Copepoda ... 5
- Cladocera ... 5
- Isopoda ... 5
- Ostracoda ... 3
- *Paranephrops* ... 5
- *Paratya* ... 5
- Tanaidacea ... 4

**Acarina** ... 5

**Mollusca**
- *Ferrissia* ... 3
- *Glyptophysa* ... 5
- *Gyraulus* ... 3
- *Latia* ... 3
- Lymnaeidae ... 3
- *Melanopsis* ... 3
- *Physa* ... 3
- *Potamopyrgus* ... 4
- Sphaeriidae ... 3

- Oligochaeta ... 1
- Hirudinea ... 3
- Platyhelminthes ... 3
- Nematoda ... 3
- Nematomorpha ... 3
- Nemertea ... 3
- Cnidaria
- *Hydra* ... 3

## Appendix 5.

**Summary of aquatic macroinvertebrates in Whareroa Stream network.**
A1-E1 = November 2006; A2-E2 = March 2007

| | A 1 | A 2 | B1 | B 2 | C1 | C 2 | D1 | D 2 | E1 | E 2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Aoteapsyche | 0 | 0 | 1 | 0 | 1 | 3 | 2 | 42 | 2 | 8 |
| Austroclima | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Austrosimulium | 8 | 0 | 43 | 35 | 160 | 36 | 4 | 27 | 5 | 20 |
| Austroperla | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Archicauliodes | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 |
| Deleatidium | 0 | 0 | 14 | 111 | 104 | 94 | 340 | 524 | 276 | 56 |
| Chironomae | 1 | 0 | 8 | 0 | 126 | 3 | 69 | 0 | 2 | 22 |
| Coloburiscus | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Elmidae | 0 | 0 | 0 | 30 | 1 | 1 | 0 | 14 | 0 | 3 |
| Eriopterini | 0 | 0 | 0 | 0 | 4 | 1 | 0 | 1 | 0 | 4 |
| Hexatomini | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hirudinea | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrobiosis | 1 | 6 | 1 | 2 | 4 | 9 | 12 | 4 | 11 | 3 |
| Hydrophilidae | 0 | 6 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| Helicopsyche | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 |
| Hydrobiosella | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19 | 0 | 3 |
| Isopodae | 2 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Nothodixa | 0 | 0 | 1 | 5 | 2 | 9 | 0 | 6 | 0 | 0 |
| Neppia | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Olinga | 2 | 0 | 0 | 1 | 1 | 1 | 8 | 20 | 14 | 5 |
| Oligochaete | 4 | 2 | 0 | 9 | 4 | 0 | 0 | 2 | 3 | 10 |
| Paratya | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paracalliope | 0 | 419 | 100 | 10 | 3 | 98 | 2 | 1 | 0 | 0 |
| Potamopyrgus | 139 | 76 | 10 | 108 | 244 | 382 | 56 | 186 | 13 | 12 |
| Physa | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pycnocentrodes | 2 | 0 | 20 | 2 | 0 | 0 | 2 | 4 | 25 | 1 |
| Pycnocentria | 0 | 0 | 0 | 249 | 0 | 0 | 0 | 5 | 0 | 0 |
| Psilochorema | 0 | 0 | 5 | 0 | 7 | 3 | 0 | 1 | 0 | 5 |
| Sigara | 0 | 1 | 7 | 0 | 8 | 0 | 39 | 0 | 15 | 0 |
| Tanypodia | 3 | 20 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 0 |
| Xanthocnemis | 4 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Zelandoperla | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Zephlebia | 0 | 0 | 0 | 0 | 15 | 0 | 2 | 0 | 1 | 0 |

## Summary of aquatic macroinvertebrate distribution

| | Nov 2006 | Mar-07 | EPT | MCI |
|---|---|---|---|---|
| Aoteapsyche | 6 | 53 | T | 4 |
| Austroclima | 1 | 0 | E | 9 |
| Austrosimulium | 220 | 118 | Diptera | 3 |
| Austroperla | 1 | 0 | P | 9 |
| Archicauliodes | 5 | 0 | Megalopt | 7 |
| Deleatidium | 734 | 785 | E | 8 |
| Chironomae | 206 | 25 | Diptera | 1 |
| Coloburiscus | 0 | 1 | E | 9 |
| Elmidae | 1 | 48 | Diptera | 6 |
| Eriopterini | 4 | 6 | Diptera | 9 |
| Hexatomini | 1 | 0 | Diptera | 5 |
| Hirudinea | 1 | 0 | Leech | 3 |
| Hydrobiosis | 29 | 24 | T | 5 |
| Hydrophilidae | 3 | 6 | Coleopt | 5 |
| Helicopsyche | 0 | 4 | T | 10 |
| Hydrobiosella | 0 | 22 | T | 9 |
| Isopodae | 2 | 11 | Crustacea | 5 |
| Nothodixa | 3 | 20 | Diptera | 5 |
| Neppia | 1 | 1 | Flatworm | 3 |
| Olinga | 25 | 27 | T | 9 |
| Oligochaete | 11 | 23 | Worms | 1 |
| Paratya | 2 | 0 | Crustacea | 5 |
| Paracalliope | 105 | 528 | Crustacea | 5 |
| Potamopyrgus | 462 | 854 | Mollusca | 4 |
| Physa | 1 | 1 | Mollusca | 3 |
| Pycnocentrodes | 49 | 7 | T | 5 |
| Pycnocentria | 0 | 254 | T | 7 |
| Psilochorema | 12 | 9 | T | 8 |
| Sigara | 69 | 1 | Hemiptera | 5 |
| Tanypodia | 6 | 21 | Diptera | 5 |
| Xanthocnemis | 7 | 0 | Odonata | 5 |
| Zelandoperla | 0 | 1 | P | 10 |
| Zephlebia | 18 | 0 | E | 7 |

# Appendix 6.

**Table 1.2 Levels of the REC hierarchy that describe particular physical processes and characteristics in rivers**

| Factor | Processes being described by this classification level | Physical characteristics that are discriminated at this level |
|---|---|---|
| Climate | Climate influences precipitation (how much rain an area receives), the amount of evapotranspiration occurring in the catchment, and the air temperature and the amount of sunshine the river receives, which together influence heating and cooling of water. | Seasonality of flow and thermal regime. High and low flow frequencies. Very broad discrimination of water chemistry (quality). |
| Topography | Catchment topography strongly influences how precipitation is stored (due to snow pack and lakes) and released from a catchment as well as erosion and transport of sediment. Topography also influences small-scale climate variation within a catchment. | Further (more specific) discrimination of the seasonality of the flow and thermal regimes, frequency of high flows. General discrimination of sediment transport regimes. |
| Geology | Catchment geology influences rates of erosion and chemical weathering of underlying rocks including nutrient release. Catchment geology influences aspects of hydrology, including groundwater storage and release (i.e. base flow conditions) | The Geology level discriminates: low flow magnitude, sediment supply, water chemistry (e.g. inorganic nutrient status, pH and dissolved and suspended inorganic matter) and channel substrate. |
| Land-Cover | Catchment land cover influences surficial erosion of soil, supply of soil derived water column constituents during rainfall and surface runoff including nutrients and sediments | The land cover level further discriminates the frequency and duration of low flow and water chemistry including total nutrients and organic matter. |
| Network-Position | Attenuation of many fluxes (e.g. flow, sediment) by catchment storage | Flux of sediment, water, and hydro-chemicals. Distribution of flow rates. Flood intensity. |
| Valley-Landform | Local hydraulic processes of erosion and deposition. | Valley-Landform influences channel shape and thus, hydraulic conditions (water velocity and depth), bank-full discharge, habitat volume, local flood power, sediment size range, and riparian conditions. The exact characteristics are, in part, determined by the higher order factors. |

from New Zealand River Environment Classification User Guide. (2004) P 16.

## Appendix 7. Worksheet for RMC assessment.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | | **Date** | | **Length Inspected (m)** | | | | | |
| **Widths (m)** | **water** | | **channel** | | **bankfull** | | **valley bottom** | | |
| **Average bank height (m)** | **left** | | **right** | | **% riffle/run/pool** | | | | |
| **Channel shape** | channelised | straight | meandering | sinuous | **Valley form** | V | U | plain | |
| **Streambed** | clay | mud | silt | sand | gravel | cobble | bedrock | | |
| **Stream shade ratio (bank+veg/width)** | | | | | | | | | |
| **Macrophytes** | **% cover** | | **Type =** | | | | | | |
| **Periphyton** | none | slippery | obvious | abundant | excessive (FA>80%) | | | | |
| **Woody debris** | absent | sparse | common | abundant | | | | | |
| **Streambank stability** | **% stable** | | **% undercut** | | **%slumping** | | **% earthflow** | | |
| **Stabilised by** | grasses | shrubs | trees | bedrock | riprap | | | | |
| **Riparian vegetation cover** | rock | bare soil | annuals | grass | toetoe | flax | | | |
| ferns | treeferns | low shrubs | high shrubs | native trees | coniferous | deciduous | | | |
| **Dominant riparian plant species** | | | | | | | | | |
| **Stock access to the stream** | **Left** | Yes | No | **Right** | Yes | No | | | |
| **Stock damage** | none | minor | moderate | extensive | | | | | |
| **Local drainage** | **slope length (m)** | | **Land slope class** | <2° | 2-5° | 5-10° | 10-15° | 15-25° | |
| **Riparian wetlands (on terraces above channel)** | Yes | No | | | | | | | |
| **Riparian land use** | **Right bank** | conservation | filter strip | woodlot | esplanade reserve | | | | |
| dairy | cattle | sheep | deer | crop | horticulture | stopbank | whitebaiting | | |
| waterfowl shooting | engineered floodway | other: | | | | | | | |
| **Left bank** | conservation | filter strip | woodlot | esplanade reserve | dairy | | | | |
| cattle | sheep | deer | crop | horticulture | stopbank | whitebaiting | | | |
| waterfowl shooting | engineered floodway | other: | | | | | | | |
| **General land use** | native forest | plantation forest | sheep / beef | deer | dairy | horticulture | peri-urban | | |
| **Riparian Function Ratings: (current / potential; 0 = absent, 5 = very highly active)** | | | | | | | | | |
| **Bank stabilization** | / | **Overland filter flow** | / | **Plant nutrient uptake** | / | | | | |
| **Denitrification** | / | **Shade** | / | **Wood input** | / | | | | |
| **Leaf litter input** | / | **Fish cover** | / | **Recreation** | / | | | | |
| **Downstream flood control** | / | **Aesthetics** | / | | | | | | |

# Appendix 8.

## RMC Scoring for south branch of Whareroa Streams

| SITE | | A | B | C | D | E |
|---|---|---|---|---|---|---|
| DATE | | 27/1/07 | 27/1/06 | 2/12/06 | 2/12/06 | 2/12/06 |
| **Spatial Scale & Physical attribute** | | | | | | |
| **A. Catchment** | | | | | | |
| Source of flow index (SOF) | 1 = Lowland<br>2 = Hill<br>3 = Mountain | 1 | 1 | 2 | 2 | 2 |
| Average elevation of catchment (m) | | 110 | 166.17 | 176.7 | 265.9 | 248.45 |
| Dominant catchment baserock geology index | 1 = Soft sedimentary<br>2 = Alluvium & sand<br>3 = Miscellany<br>4 = Volcanic base<br>5 = Hard sedimentary | 1, 2 | 5 | 5 | 5 | 5 |
| Catchment spatial average slope | | 12.98 | 16.46 | 20.34 | 20.44 | 21.15 |
| Catchment area ($km^2$) | | 15.6105 | 6.9075 | 1.251 | 1.0134 | 1.2672 |
| Catchment land cover index | 1 = Bare<br>2 = Urban<br>3 = Pasture<br>4 = Tussock<br>5 = Exotic forest<br>6 = Scrub<br>7 = Indigenous forest | 55% pastoral; 45% scrub | 100% pastoral | 69% pastoral; 19% scrub | 81% pastoral; 12% scrub | 92% pastoral 5% scrub |
| **Valley segment** | | | | | | |
| Riparian land use | Cattle, Conservation, Crop. Dairy, Forestry, Horticulture, Sheep, Urban | parkland | cattle | cattle | cattle | cattle |
| Channel shape category | 1 = channelised<br>2 = straight<br>3 = meandering<br>4 = sinuous | 1 | 2 | 3 | 3 | 3 |
| Valley bottom width category | 1 = <20m<br>2 = 20-50m<br>3 = 50-200m<br>4 = 200-1000<br>5 = >1000m<br>6 = "plains" | 6 | 6 | 2 | 3 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| REC channel slope ($cm^2/m$) | Internode difference in elevation/reach length | | | | | |
| REC segment mean air temperature | July min (°C)<br>January max(°C) | Min 7.7°<br>Max 18.7° | Min 7.9°<br>Max 20.3° | Min 7.1°<br>Max 17.7° | Min 6.8°<br>Max 17.6° | Min 7.2°<br>Max 18.1° |
| REC segment annual rainfall (mm) | Predicted mean local rainfall | 400-1200mm | | | | |
| REC average land slope of segment's local catchment | Derived form REC digital elevation model for the land draining directly to the local stream segment | LG <0.02° | LG <0.02° | HG >0.04° | HG >0.04° | HG >0.04° |
| Mean annual low flow (L/s) | | 156.65 | 71.77 | 13.35 | 10.88 | 13.61 |
| REC reach elevation (m) | Above sea level | 16 | 19 | 165 | 154 | 61 |
| Domain land drainage class | 1 = very poor<br>2 = poor<br>3 = impeded<br>4 = moderate<br>5 = good | 2 | 2 | 3 | 3 | 4 |
| Domain acid soluble P class | 1 = very low<br>2 = low<br>3 = moderate<br>4 = high<br>5 = very high | 1.51 | 1.46 | 1.02 | 1.31 | 1.13 |
| Domain soil age class | 1 = recent<br>2 = older | 1 | 1 | 1 | 1 | 1 |
| Domain exchangeable Calcium class | 1 = low<br>2 = moderate<br>3 = high<br>4 = very high | 1.48 | 1.34 | 1.03 | 1.32 | 1.13 |
| Domain induration (hardening) | 1 = nonindurated<br>2 = very weakly<br>3 = weakly<br>4 = strongly<br>5 = very strongly indurated | 2.55 | 2.96 | 3.9 | 3.03 | 3.6 |
| **Reach** | | | | | | |
| Distance from sea (m) | | 1.13 | 3.06 | 5.7 | 6.18 | 6.08 |
| Water width (m) | Estimate average of stream at low flow | 5.43 | 3.82 | 1 | 1 | 2.68 |
| Non-vegetated width (m) | Estimate of channel width lacking terrestrial vegetation | 5.43 | 4.32 | 0.3 | 1.57 | 0.6 |
| Bankful width (m) | Total width at bankful discharge | 9.55 | 6.06 | 2.09 | 1.5 | 3.28 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Floodplain width (m) | | 4.13 | 2.55 | 0.73 | 4.23 | 1.86 |
| Wet/dry index | 0 = dry channel<br>1 = water present in channel | 1 | 1 | 1 | 1 | 1 |
| Channel slope index (°) | 1 = <0.2°;<br>2 = 0.2°-0.5°<br>3 = 0.5°-1.0°<br>4 = 1.0°-2.0°<br>5 = 2.0°-4.0°<br>6 = >4° | 3 | 3 | 6 | 6 | 6 |
| Local land slope index | 1 = <2°<br>2 = 2.0°-5.0°<br>3 = 5.0°-15.0°<br>4 = 15°-25°<br>5 = 25°-35°<br>6 = >35° | 3 (6.47°) | 3 (3.04°) | 3 (15.25°) | 3 (24.54°) | 3 (20.11°) |
| Local land slope length index | 1 = plains & <10m<br>2 = 10-50m<br>3 = >50-200m<br>4 = >500m | 1 | 1 | 2 | 2 | 2 |
| Substrate composition | bedrock, boulder, cobble, gravel, sand, silt, clay | silt, bedrock | cobble | cobble | cobble | cobble |
| Vegetation height (m) | Average vegetation height within 10m | 0.5 | 5 | 1 | 5 | 10 |
| Shade ratio | Bank + vegetation height/ channel width | 1.5/5.4 =0.03 | 2.0/3.9 =0.51 | 1.0/1.4 =0.71 | 5.0/1.5=3.3 | 6.5/3.1 =2.09 |
| Bank height (m) | Estimate an average bank height | 1 | 1.5 | 1 | 1.5 | 5.5 |
| Periphyton categories | 0 = none<br>1 = slippery<br>2 = obvious<br>3 = abundant<br>4 = excessive (>80%FGA) | 4 | 0 | 3 | 1 | 1 |
| Macrophyte species & % cover | Species present, % total bed covers. Bryophyte cover noted separately | water celery 20%; water cress 20% | water celery 10%; water cress 10% | water cress 70% | water cress 5% | 0 |
| Woody debris index | 0 = absent<br>1 = sparse<br>2 = common<br>3 = abundant | 0 | 1 | 1 | 1 | 1 |
| Stock access index | 0 = no access<br>1 = one bank<br>2 = access to both banks | 0 | 0 | 2 | 2 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Stock bank damage index | 0 = none<br>1 = minor<br>2 = moderate<br>3 = extensive | 0 | 0 | 3 | 1 | 0 |
| Stream bank stability | Assessment of the % bank stable undercut or slumped | Stable 100%; slumping 10% | stable 100%; undercut 10% | Stable 10% slumping 90% | stable 100% undercut 10% | stable 100%; undercut 30% |
| Riparian veg. & bank cover | List of dominant riparian vegetation | | | | | |
| Dominant riparian vegetation index | 0 = bare ground<br>1 = grass<br>2 = wetland<br>3 = low shrub<br>4 = high shrub<br>5 = deciduous<br>6 = willows<br>7 = coniferous<br>8 = eucalyptus<br>9 = native | 1 | 4,3 | 1,3 | 3,1 | 9 |
| Riparian wetland index | 0 = absent<br>1 = present | 0 | 0 | 0 | 0 | 0 |
| Stock fencing index | 0 = none<br>1 = one side fenced<br>2 = both sides fenced | 2 | 2 | 0 | 0 | 2 |
| Stock damage classes | 0 = none<br>1 = minor<br>2 = moderate<br>3 = extensive | 0 | 0 | 3 | 1 | 0 |
| Riparian fencing | %of each bank fenced and bank to fence distance | R&L 100% R100m, L30m | R&L 100% R30m, L400m | 0 | 0 | R&L 100% L40m, R10m |
| Fencing type index | 0 = none<br>1 = electric 1 wire<br>2 = electric 2 wires<br>3 = post & batten, or 5-7 wires electric, or deer fence | 3 | 3 | 0 | 0 | 3 |

# Appendix 9

## KEY NATIVE ECOSYSTEMS

## Description and Scoring Form

THE REGIONAL COUNCIL
*caring about you & your environment*

| | |
|---|---|
| DoC ID no. (if known) | 702 |
| Site name | Whareroa Farm |
| Ecological region | Manawatu |
| NZMS 260 Map no. | R26 |
| Grid Reference | 767-233 |
| Area (ha) | 3.6 |
| Altitude range | 40-100 |
| Date | 2-Feb 1999 |
| Time (24 hr ) start/stop | 11-12pm |
| Authorised person | Mark & Glen |
| Protect/ Type (Auth/body) | Landcorp |
| Protection Status | Covenant |

**General Description**

A patch of bush on that is fenced off and not grazed.

**Significant Values** (Vegetative association)

Tawa and kohekohe forest on hill country.

| | | |
|---|---|---|
| (1) DoC Plant Score | 2.0 | |
| (2) DoC Animal Score | 3.0 | |
| (3) DoC Vulnerability Score | 1.5 | |
| (4) DoC Primary Score | 4.5 | (3) X highest of (1)or(2) |
| (5) Local Significance Score | 0.0 | |
| **(6) Regional Priority Score** | 4.5 | (4) + (5) |

**Other Relevant Factors**

Fenced and has a covenant on this patch of bush.

**Plant Species known to be present**

| | |
|---|---|
| Emergent Canopy trees | |
| Canopy trees | Titoki, Kohekohe, Tawa, Ngaio, Pukatea, Rewarewa, Miro |
| Middle Storey | Mahoe, Lancewood, Totara, Pohutukawa |
| Lower Storey & shrubs | *Muehlenbeckia australis,* Cop lucida, Bracken, Rata, Hanging spleenwort, Kawakawa, Kaikomako, Leather leaf fern, Frgrant fern, Hangehange, Kiekie, Pigeonwood, Cop spp, Native jasmine, Cop grand, Shining spleenwort, Common shield fern, Supplejack, Hounds tongue fern, Sickle spleenwort, Button fern, Totara, Hen and chicken fern, Red matipo, Broadleaf, Tree astelia, *Adiantum raddianum,* Hook grass, Wharangi, Rangiora, Kiekie |
| Other | Sycamore, Macrocarpus |

**Animal Species known to be present**
(include birds, reptiles, mammals, invertebrates, fish, pests)

Fantail, Blackbird, Magpie, Cicada, Dragonfly, Woodpigeon

**Threatened Species for Wellington Conservancy**

| | |
|---|---|
| **Category A** | |
| **Category B** | Woodpigeon |
| **Category C** | |
| **Priority Species** | |

**Nationally Threatened Species**

# KEY NATIVE ECOSYSTEMS

## Description and Scoring Form

THE REGIONAL COUNCIL
*caring about you & your environment*

| | |
|---|---|
| DoC ID no. (if known) | 703 |
| Site name | Whareroa Farm |
| Ecological region | Manawatu |
| NZMS 260 Map no. | R26 |
| Grid Reference | 772-238 |
| Area (ha) | 3.8 |
| Altitude range | 20-100 |
| Date | 2-Feb 1999 |
| Time (24 hr ) start/stop | 11.40-1pm |
| Authorised person | Mark & Glen |
| Protect/ Type (Auth/body) | Landcorp |
| Protection Status | Covenant |

**General Description**

A patch of bush with a public walkway in it, which is on the edge of SH1.

**Significant Values (Vegetative association)**

Tawa and kohekohe hill country.

| | | |
|---|---|---|
| (1) DoC Plant Score | 2.0 | |
| (2) DoC Animal Score | 3.0 | |
| (3) DoC Vulnerability Score | 1.5 | |
| (4) DoC Primary Score | 4.5 | (3) X highest of (1)or(2) |
| (5) Local Significance Score | 1.0 | |
| **(6) Regional Priority Score** | 5.5 | (4) + (5) |

**Other Relevant Factors**

Partially fenced. Not stock proof.

**Plant Species known to be present**

| | |
|---|---|
| Emergent Canopy trees | |
| Canopy trees | Rewarewa, Tawa, Kohekohe, Karaka, Nikau, Totoki |
| Middle Storey | Kaikomako, Lancewood, Mamaku, Pukatea, Kahikatea |
| Lower Storey & shrubs | Kiekie, Muehlenbeckia spp, Rata vines, Kawakawa, Pigeonwood, Cop spp, Native jasmine, Common sheild fern, Astelia, Coastal tree daisy, Mahoe, Hangehange, Tutu, *Adiantum raddianum,* Hanging spleenwort, Hookgrass, Button fern, Ngaio, Hanging spleenwort, Wheki, Supplejack, Lancewood, Titoki, Leather leaf fern |
| Other | Gorse |

**Animal Species known to be present**
(include birds, reptiles, mammals, invertebrates, fish, pests)

Pukeko, Eastern rosella, Fantail, Rabbit, Woodpigeon, Cicada, Goldern finch

**Threatened Species for Wellington Conservancy**

| | |
|---|---|
| Category A | |
| Category B | Woodpigeon |
| Category C | |
| Priority Species | |

**Nationally Threatened Species**

# KEY NATIVE ECOSYSTEMS

## Description and Scoring Form

THE REGIONAL COUNCIL
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| | |
|---|---|
| DoC ID no. (if known) | 704 |
| Site name | Whareroa Farm |
| Ecological region | Manawatu |
| NZMS 260 Map no. | R26 |
| Grid Reference | 773-234 |
| Area (ha) | 1.7 |
| Altitude range | 60-80 |
| Date | 2-Feb 1999 |
| Time (24 hr ) start/stop | 10.45-11.30am |
| Authorised person | Mark & Glen |
| Protect/ Type (Auth/body) | Landcorp |
| Protection Status | Covenant |

**General Description**

A patch of bush at the bottom of a hill face.

**Significant Values (Vegetative association)**

Kohekohe and tawa forest on colluvium.

| | | |
|---|---|---|
| (1) DoC Plant Score | 2.0 | |
| (2) DoC Animal Score | 2.0 | |
| (3) DoC Vulnerability Score | 1.5 | |
| (4) DoC Primary Score | 3.0 | (3) X highest of (1)or(2) |
| (5) Local Significance Score | 1.0 | |
| **(6) Regional Priority Score** | 4.0 | (4) + (5) |

**Other Relevant Factors**

Not fenced. Stock have access.

**Plant Species known to be present**

| | |
|---|---|
| Emergent Canopy trees | |
| Canopy trees | Tawa, Kohekohe, Nikau, Karaka, Rewarewa |
| Middle Storey | Wharangi, Pukatea |
| Lower Storey & shrubs | Broadleaf, Cop spp, Northern rata, Mahoe, Poroporo, Kaikomako, Common shield fern, Leather leaf fern, *Adiantum raddianum,* Astelia, Kawakawa, Lancewood, Fragrant fern, Hangehange, Sickle spleenwort, Tauhinu, Hanging spleenwort, Palm fern, Wheki, Red matipo, Bracken, Button fern, Pigeonwood, Supplejack, Kiekie |
| Other | Gorse, Inkweed |

**Animal Species known to be present**
(include birds, reptiles, mammals, invertebrates, fish, pests)

Hawk, Magpie, Fantail, Hare, Possum, Eastern rosella, Wasp nest

**Threatened Species for Wellington Conservancy**

| | |
|---|---|
| **Category A** | |
| **Category B** | |
| **Category C** | |
| **Priority Species** | |

**Nationally Threatened Species**

# KEY NATIVE ECOSYSTEMS

## Description and Scoring Form

THE REGIONAL COUNCIL
*caring about you & your environment*

| | |
|---|---|
| DoC ID no. (if known) | 705 |
| Site name | Whareroa Farm |
| Ecological region | Manawatu |
| NZMS 260 Map no. | R26 |
| Grid Reference | 775-232 |
| Area (ha) | 1.5 |
| Altitude range | 80-140 |
| Date | 2-Feb 1999 |
| Time (24 hr ) start/stop | 10-11am |
| Authorised person | Mark & Glen |
| Protect/ Type (Auth/body) | Landcorp |
| Protection Status | Covenant |

**General Description**

A patch of forest on a hill side facing north.

**Significant Values** (Vegetative association)

Kohekohe forest with the occasional podocarp on hill country.

| | | |
|---|---|---|
| (1) DoC Plant Score | 2.0 | |
| (2) DoC Animal Score | 3.0 | |
| (3) DoC Vulnerability Score | 1.5 | |
| (4) DoC Primary Score | 4.5 | (3) X highest of (1)or(2) |
| (5) Local Significance Score | 0.0 | |
| **(6) Regional Priority Score** | 4.5 | (4) + (5) |

**Other Relevant Factors**

Not fenced and stock have access.

**Plant Species known to be present**

| | |
|---|---|
| Emergent Canopy trees | Totara |
| Canopy trees | Tawa, Nikau, Kohekohe, Miro, Karaka, Kahikatea, Matai, Rimu |
| Middle Storey | Pigeonwood, Pukatea, Titoki, Red matipo |
| Lower Storey & shrubs | White rata, Kaikomako, Poroporo, Leather leaf fern, Hanging spleenwort, Ngaio, Lancewood, Mahoe, Native jasmine, Tauhinu, Cop spp, Mamaku, Manuka, Kiekie, Putaputaweta, Kawakawa, Supplejack, Broadleaf, Hen and chicken fern |
| Other | Inkweed |

**Animal Species known to be present**
(include birds, reptiles, mammals, invertebrates, fish, pests)

Woddpigeon, Spur winged plover, Magpie,
Fantail, Possum, Eastern rosella, Blackbird

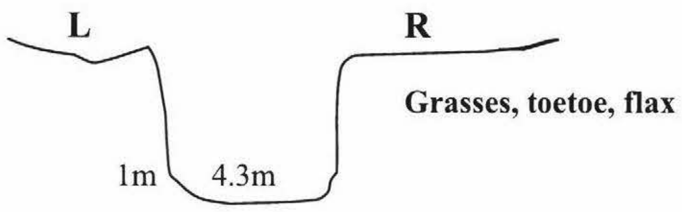
**Threatened Species for Wellington Conservancy**

| | |
|---|---|
| Category A | |
| Category B | Woodpigeon |
| Category C | |
| Priority Species | |

**Nationally Threatened Species**

## Appendix 10. Shape of valleys reviewed for riparian characteristics.

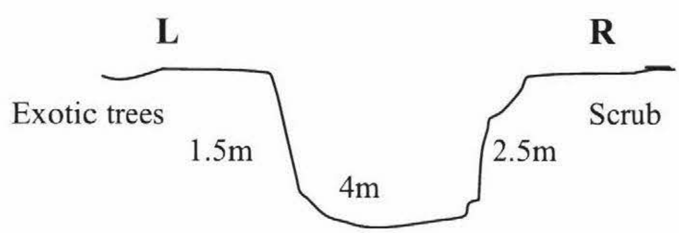
**Site A.**




Channelised.
**Nutrient levels high**

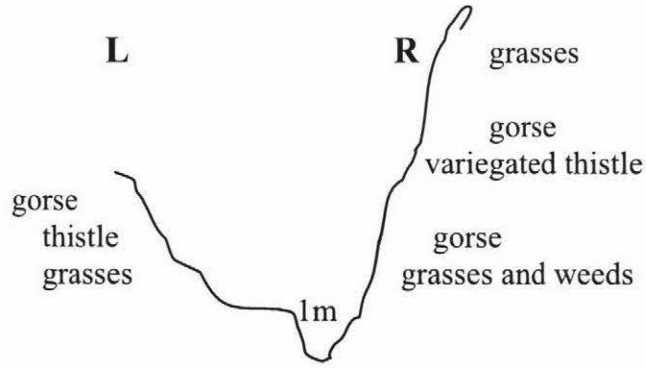
Riparian management plan in place.
Fencing >60m both sides

**Site B.**




Exotic trees established on left bank
Scrub on right bank
Abundant water celery and cress
Potential for tree planting on R bank and streamside grasses L bank.

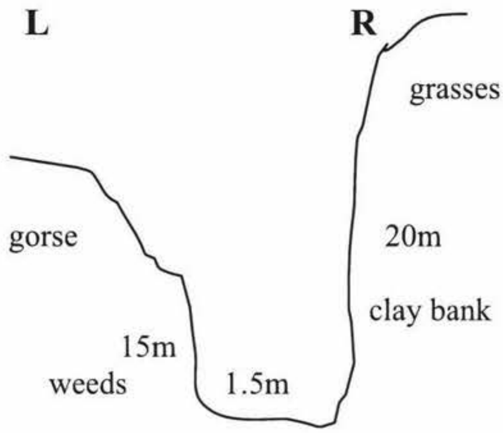
**Site C.**




Ecological 'disaster'.
**Abundant watercress; Major cattle damage to banks**

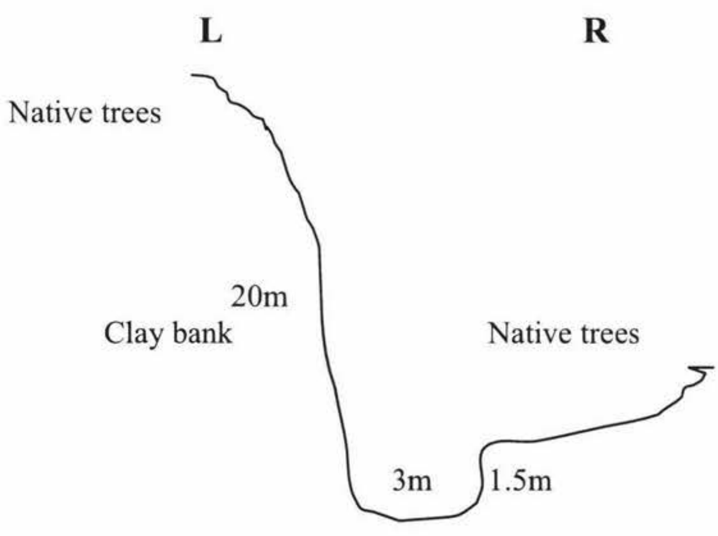
No fencing
No effective regeneration. **Priority potential for riparian planting.**

**Site D.**




Fencing 20m above right bank.
Overland filter flow effective through gorse and grasses on left bank
Some watercress
Potential for streamside grasses, and long term shade trees on banks
Requires fencing at top of left bank
Bush remnant on hillside above left bank.

**Site E.**




Weeds appearing at margins
Fencing 30m right bank, >60m left bank
Farmland above and below site
Bush includes kohekohe, titoki, matai, kawakawa, mahoe

## Appendix 11. Inventory of weeds found in riparian zones up to 10m wide at Study sites

| Botanic name | Common name | Native/ Exotic | Sites found |
|---|---|---|---|
| *Achillea millefolium* | Yarrow | E | A |
| *Anthemus cotula* | Stinking mayweed | E | C |
| *Apium prostatum* | Water celery | N | A B |
| *Castylegia sepium* | Convulvus | E | B |
| *Chenopodium album* | Fathen | E | A D |
| *Cirsium vulgare* | Scotch thistle | E | A B C D |
| *Cirsium arvense* | California thistle | E | D |
| *Conium maculatum* | Hemlock | E | D |
| *Crepiscapillaris* | Hawksbeard | E | A C |
| *Daucus carota* | Wild carrot | E | B |
| *Digitalis purpurea* | Foxglove | E | C D |
| *Lotus pedunculatus* | Lotus | E | A C D |
| *Myositis sylvaticus* | Forget-me-not | E | C |
| *Phytolacca octandra* | Inkweeed | E | A D |
| *Plantago major* | Plantain | E | A B |
| *Polygonum persicaria* | Willow weed | E | A D |
| *Polygonum hydropiper* | Water pepper | E | D |
| *Prunella vulgaris* | Selfheal | E | A C |
| *Ranunculaus parviflorus* | Buttercup | E | A C D |
| *Rorippa nasturtium-aquaticum* | Water cress | E | A B C D |
| *Rumex crispus* | Dock | E | A B |
| *Rumex acetosalla* | Sheeps sorrel | E | A C D |
| *Salvia spp* | Salvia | E | B |
| *Senecio jacobea* | Ragwort | E | A D |
| *Senecio glomeratus* | Fireweed | E | B |
| *Solanum nigrum* | Black nightshade | E | B |
| *Sonchus asper* | Prickly sow thistle | E | A |
| *Sybilum marianum* | Variegated thistle | E | A C D |
| *Taraxacum officinales* | Dandelion | E | C D |
| *Trifolium repens* | White clover | E | A B C D |
| *Trifolium arvense* | Haresfoot trefoil | E | D |
| *Ulex europaeus* | Gorse | E | B C D |
| *Verbascum thapsus* | Aarons rod | E | C |
| *Zantedeschia aethiopica* | Arum lily | E | B E |

## Appendix 12. Whareroa Farm – Sheep and Beef Unit, Paekakariki, Kapiti District

**MAP:** NZMS 260 Sheet R26 Paraparaumu.
**ECOLOGICAL DISTRICT:** Tararua 38.01.
**GEOLOGY:** Triassic-Jurassic greywacke and argillite. Possible minor spilitic tuff and lava, chert and limestone. (*NZ Geological Survey – North Island.* 1:1,000,000. DSIR 1972)
**AREA:** 447.5 ha.

**RAINFALL:** 500-1500 mm.

**TENURE:** Purchased by the Crown from Landcorp in 2005.

**MANAGEMENT:** under discussion.
**WHAREROA COVENANT -** Conservation Unit Number: R26040. 21.2070 ha. Seven remnants of secondary forest on the farm. Administered by Waikanae Area Office, Department of Conservation.
**LEGAL STATUS:** Conservation Covenant, Reserves Act 1977.
**HISTORY:** The name of the farm comes from Whareroa Pa, which was occupied by Ngati Maru people who lived on the coast west of the farm during the 19th century. Under the Department of Lands and Survey, and later, Landcorp, Whareroa Farm was run as two units: a sheep and beef unit, the site of our field trip, east of SH1 and NIMT railway, and a dairy unit west of SH1/NIMT. (*Whareroa Farm – sheep and beef unit.* Pamphlet, Department of Lands and Survey, December 1983).

Lists compiled by Glen Falconer and Mark McAlpine on 2/2/99 during a ????-hour survey. Additions made by Wellington Botanical Society/Whareroa Guardians Community Trust on 3 November 2007 during a 6-hour visit. White maire added by Ann Evans November 2007.

In Maaori names, double vowels are used in lieu of macrons.

### LIST 1: SOME INDIGENOUS VASCULAR PLANTS

* = not native to Tararua Ecological District
< = not seen on 3/11/07 field trip
(unc) = uncommon – one example seen
(P) = planted

| BOTANICAL NAME | MAAORI NAME | COMMONNAME |
|---|---|---|
| **GYMNOSPERM TREES** | | |
| Dacrycarpus dacrydioides | kahikatea | kahikatea |
| Dacrydium cupressinum | rimu | rimu |
| Podocarpus totara | tootara | totara |
| Prumnopitys taxifolia | mataii | matai |
| < Prumnopitys ferruginea | miro | miro |

**MONOCOT TREES**

| | | |
|---|---|---|
| Cordyline australis | tii koouka | cabbage tree |
| Rhopalostylis sapida | niikau | nikau |

**DICOT TREES AND SHRUBS**

| | | |
|---|---|---|
| Alectryon excelsus | tiitoki | titoki |
| Aristotelia serrata | makomako | wineberry |
| Beilschmiedia tawa | tawa | tawa |
| Brachyglottis repanda | rangiora | rangiora |
| Carpodetus serratus | putaputaweetaa | putaputaweta |
| Coprosma grandifolia | kaanono | kanono |
| < Coprosma lucida | karamu | karamu |
| Coprosma repens | taupata | taupata |
| Coprosma rhamnoides | | |
| Coprosma robusta | karamu | karamu |
| Corynocarpus laevigatus | karaka | karaka. |
| Dysoxylum spectabile | kohekohe | kohekohe |
| Elaeocarpus dentatus | hiinau | hinau |
| Fuchsia excorticata (unc) | kootukutuku | tree fuchsia |
| Geniostoma ligustrifolium | | |
| var. ligustrifolium | hangehange | hangehange |
| Griselinia littoralis | papaauma | broadleaf |
| Griselinia lucida | puka | broadleaf |
| Hedycarya arborea | porokaiwhiri | pigeonwood |
| Knightia excelsa | rewarewa | rewarewa |
| Kunzea ericoides | kaanuka | kanuka |
| Laurelia novae-zelandiae | pukatea | pukatea |
| Macropiper excelsum | kawakawa | kawakawa |
| Melicope ternata | wharangi | wharangi |
| Melicytus ramiflorus | maahoe | mahoe |
| * Metrosideros excelsa | poohutukawa | pohutukawa |
| Myoporum laetum | ngaio | ngaio |
| Myrsine australis | maapou | mapou |
| Ozothamnus leptophyllus | tauhinu | tauhinu |
| Pennantia corymbosa | kaikoomako | kaikomako |
| * Pittosporum crassifolium | | |
| Plagianthus regius (P) | maanatu | lowland ribbonwood |
| Pseudopanax arboreus (unc) | whauwhaupaku | five-finger |
| Pseudopanax crassifolius | horoeka | lancewood |
| * Pseudopanax hybrids & cultivars | | |
| Schefflera digitata | patee | seven-finger |
| Solanum sp. | poroporo | poroporo |
| Streblus banksii | ewekuri | large-leaved |
| milktree | | |
| Veronica stricta (sect. Hebe) | | |
| var. macroura | | |
| Weinmannia racemosa | kaamahi | kamahi |

| | | |
|---|---|---|
| **MONOCOT LIANES** | | |
| Freycinetia banksii | kiekie | kiekie |
| Ripogonum scandens | kareao | supplejack |
| | | |
| **DICOT LIANES** | | |
| Clematis paniculata | | |
| Metrosideros diffusa | raataa | white rata |
| Metrosideros fulgens | akakura | scarlet rata |
| Metrosideros perforata | akatea | clinging rata |
| Muehlenbeckia australis | poohuehue | pohuehue |
| Muehlenbeckia complexa | poohuehue | pohuehue |
| Parsonsia heterophylla | kaihua | NZ jasmine |
| Passiflora tetrandra | koohia | NZ passion flower |
| | | |
| **FERNS** | | |
| Adiantum cunninghamii | huruhuru tapairu | common maidenhair |
| Arthropteris tenella | | jointed fern |
| Asplenium bulbiferum | manamana | hen and chickens |
| Asplenium flaccidum | makawe o Raukatauri | hanging spleenwort |
| Asplenium gracillimum | | |
| Asplenium hookerianum | | Hooker's spleenwort |
| Asplenium oblongifolium | huruhuruwhenua | shining spleenwort |
| Asplenium polyodon | petako | sickle spleenwort |
| Azolla rubra | retoreto | floating fern |
| Blechnum chambersii | nini | lance fern |
| Blechnum filiforme | paanako | thread fern |
| Blechnum fluviatile | kiwakiwa | ray water fern |
| Blechnum membranaceum | | |
| Blechnum minus | kiopkio | swamp kiokio |
| Blechnum novae-zelandiae | kiokio | kiokio |
| Cyathea cunninghamii | | gully tree fern |
| Cyathea dealbata | ponga | ponga |
| Cyathea medullaris | mamaku | mamaku |
| Cyathea smithii | kaatote | soft tree fern |
| Dicksonia squarrosa | whekii | wheki |
| Diplazium australe | | |
| Hypolepis ambigua | rarauhi nehenehe | |
| Lastreopsis glabella | | smooth shield fern |
| Lastreopsis microsora | | |
| Lastreopsis velutina | | velvet fern |
| Microsorum pustulatum | koowaowao | hound's tongue |
| Microsorum scandens | mokimoki | fragrant fern |
| Paesia scaberula | maataa | ring fern |
| Pellaea rotundifolia | tarawera | round-leaved fern |
| Pneumatopteris pennigera | paakau | gully fern |
| Polystichum neozelandicum ssp. zerophyllum | pikopiko | common shield fern |
| Polystichum oculatum | pikopiko | a shield fern |
| Pteridium esculentum | raarahu | bracken |
| Pteris macilenta | titipo | sweet brake |
| Pteris tremula | turawera | shaking brake |
| Pyrrosia eleagnifolia | ota | leather-leaf fern |

**ORCHIDS**

| | | |
|---|---|---|
| Earina mucronata | peka a waka | Spring orchid |
| Pterostylis banksii | tutukiwi | a greenhood |

**GRASSES**

| | | |
|---|---|---|
| Echinopogon ovatus | | hedgehog grass |
| Microlaena stipoides | paatiitii | meadow rice grass |

**SEDGES**

| | | |
|---|---|---|
| Carex geminata | rautahi | cutty grass |
| Carex secta | puukio | |
| Cyperus ustulatus | upoko tangata | giant umbrella sedge |
| Isolepis prolifer | | three-square |
| Isolepis reticularis | | |
| Uncinia uncinata | matau a Maaui | hooked sedge |
| Uncinia "fine" | | a hooked sedge |

**RUSHES**

| | | |
|---|---|---|
| Juncus australis | wiiwii | leafless rush |
| Juncus edgariae | wiiwii | leafless rush |
| Juncus sarophorus | wiiwii | leafless rush |

**MONOCOT HERBS, other than orchids, grasses, sedges, rushes**

| | | |
|---|---|---|
| Astelia solandri | koowharawhara | perching astelia |
| Collospermum hastatum | kahakaha | a collospermum |
| Lemna minor | kaarearea | duckweed |
| Phormium sp. (P) | | a flax |
| Typha orientalis | raupoo | raupo |

**DICOT HERBS**

| | | |
|---|---|---|
| Epilobium rotundifolium | | round-leaved willow herb |
| Epilobium sp. | | a willow herb |
| Gnaphalium gymnocephalum | | creeping cudweed |
| Hydrocotyle moschata | | hairy pennywort |
| Hydrocotyle novae-zelandiae | | a pennywort |
| Lobelia anceps | punakuru | shore lobelia |
| Senecio minimus | | a fireweed |
| Stellaria parviflora | kohukohu | chickweed |

## LIST 2: SOME ADVENTIVE VASCULAR PLANTS

### GYMNOSPERM TREES

| | |
|---|---|
| Cupressus macrocarpa | macrocarpa |

### DICOT TREES AND SHRUBS

| | |
|---|---|
| Acer pseudoplatanus | sycamore |
| Cotoneaster sp. | rockspray? |
| Populus sp. | a poplar |
| Rubus fruticosus agg. | blackberry |
| Salix fragilis | crack willow |

## LIST 3: SOME INDIGENOUS BIRDS

| | | |
|---|---|---|
| Hemiphaga novaeseelandiae | kereruu | NZ pigeon |
| Rhipidura fuliginosa | piwaiwaka | fantail |

## LIST 4: SOME ADVENTIVE BIRDS

| | |
|---|---|
| Gymnorhina tibicen | Australian magpie |
| Turdus merula | blackbird |

## LIST 5: OTHER INDIGENOUS FAUNA

| | | |
|---|---|---|
| | kihikihi | cicada |