

# **The Role of Aquatic Ecosystem Sustainability in Shaping Distribution and Form of Urbanisation and Rural Development**

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## **ABSTRACT**

New Zealand community aspirations to retain estuarine and lake ecosystems in optimal ecological and aesthetic condition, are now influencing how urbanisation and rural development in respective watersheds must be modified. The cases both demonstrate the pursuit of sustainable development using ecological capacity as a yardstick, and show how ecological knowledge influences planning. Cases include the following. Neighbouring watersheds of Long Bay and Okura demonstrate urban and lifestyle block developments respectively, designed to minimize stormwater and contaminant discharge to a marine reserve. 'Low impact design' principles are applied to the Long Bay watershed. Biodiversity is protected and enhanced. Christchurch City Council's Waterways and Wetlands Asset Management Strategy demonstrates Council aspirations to restore components of a major wetland ecosystem upon which the city was built. At Whaingaroa a rural and small town community have responded to sedimentation and enrichment of their harbour by withdrawing from pastoral use and reforesting land that is riparian or very steep. The Lake Taupo community seek the means to curb the expansion of dairy farming in anticipation of increased nitrogen losses to an oligotrophic lake that is nitrogen limited. The New Zealand Resource Management Act 1991 can be used to integrate management across the land-water interface. Changing societal priorities ensure that, in the above cases, land use change is not at the expense of receiving water degradation.

## **INTRODUCTION**

New Zealand community aspirations to retain estuarine and lake ecosystems in optimal ecological and aesthetic condition, are influencing how urbanisation and rural development in watersheds must be modified. The cases described below demonstrate the pursuit of sustainable development using ecological capacity as a yardstick. They also show how ecological knowledge influences planning, how planning in New Zealand integrates such knowledge and how this contributes to sustainable development.

## **URBAN**

In the urban context ecological knowledge might best be incorporated into development through the concept and practice of Low Impact Urban Design and Development (LIUDD) which is evolving rapidly in Australia, Canada, the USA and New Zealand.

In North America, as in New Zealand, the 'low impact' approach is as much in its infancy. There are elements of LIUDD in brownfield sites in Portland-Oregon (Liptan and Murase 2002), Seattle (City of Seattle 2002) and Massachusetts (Goldsmith 2002). In western USA and throughout Canada, many Greenfield sites (for example, Simon Fraser University – Vancouver; CH2MHILL 2002) are at the

design stage only and on the brink of construction. Exemptions include sites such as Denver Colorado constructed in the 1970s in a pre-LIUIDD era but incorporating many LIUIDD elements that have been very successful (Holz pers.comm.). In addition some local councils such as in the Cities of Olympia and Lacey, Washington (Holz 2002; City of Lacey 2002; Hielema pers.comm.) have completed or progressed the writing of ordinances facilitating, or in some cases requiring a 'low impact' approach.

The Bureau of Environmental Services, Portland City, Oregon, has established a range of brownfield projects throughout the city demonstrating infiltration gardens in car parks, and the successful use of ecoroofs and raingardens on both old central city building sites and in redevelopment of apartment building complexes and city amenity blocks. These facilities are proving that a minimal discharge of stormwater from these sites is possible without infiltration to ground (Liptan and Murase 2002).

New Zealand urban cases outlined in this paper include both the design of greenfield areas (Auckland Region) and the restoration of brownfield areas (Canterbury Region). The urban and rural cases alike demonstrate how current knowledge of the dynamics of chemistry and aquatic ecology of river, lake and estuary watersheds, enables decisions to be made on appropriate future land use options that will protect or restore desired aquatic ecosystem conditions.

Although every river basin has unique characteristics and ecological sustainability issues, there is substantial opportunity to transfer knowledge and management methods between different river basins both nationally and internationally. The prevention or remediation of nutrient and sediment loss to aquatic ecosystems from intensive land use, and the conservation or restoration of biodiversity concurrent with land use intensification, are challenges common to all societies and river basin communities seeking sustainability.

### **Coastal Ecosystem Protection Constrains Urban Distribution and Form**

The first case, at the northern extremity of the Auckland Metropolitan Area, concerns neighbouring watersheds of Okura and Long Bay, both of which discharge into the Long Bay Marine Reserve (Figure 2). An ecologically productive and, by Auckland standards, relatively pristine estuary lies mostly within the Marine Reserve. The presence of the Marine Reserve adds weight to the need for conservation in both the estuary and watershed. Prior to 1996 there was a long-standing resistance by both local and regional communities to urbanisation of the watershed.

Figure 1. Location

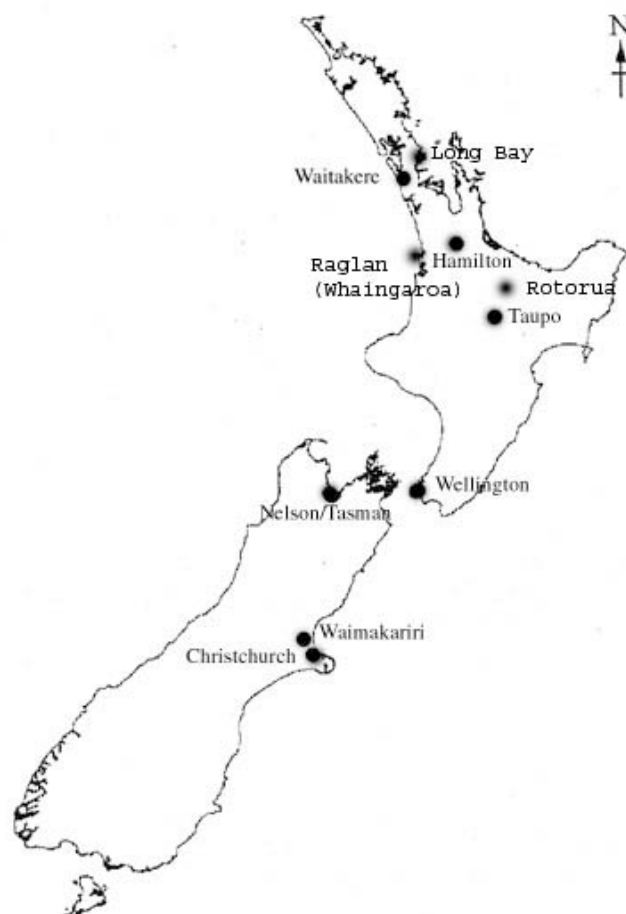
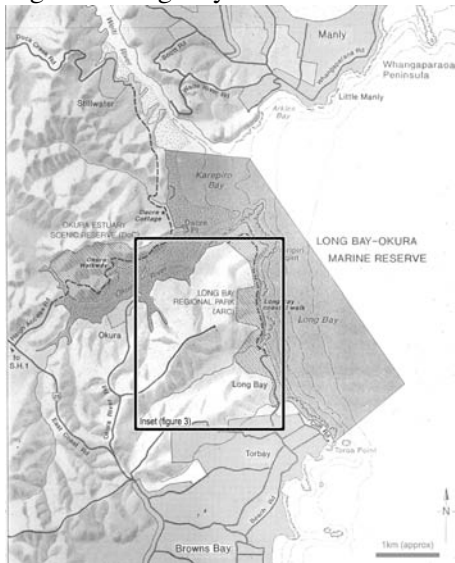


Figure 1:

Figure 2 Long Bay Marine Reserve



The Environment Court in 1997 (NSCC v. ARC, 1997) determined that the Okura watershed should remain rural but allowed for the urbanisation of the adjacent Long Bay watershed. Debate has followed as to what rural really means for the Okura watershed. Local government councils with responsibilities in the watershed have sought answers to the risks imposed on the ecology of the estuary by sediment generating development. Rural use could include hobby-farm- residential developments down to 1 hectare in area. Sediment generation on such blocks is expected to come mainly from building sites. A major motorway requiring very strict sediment control retention techniques has also recently been built through the watershed.

The National Institute of Water and Atmospheric Research (NIWA) was contracted to assess the risk to estuarine ecosystems of various land use scenarios for the Okura watershed. NIWA assessed the sensitivity of estuarine habitats to sediment deposition (Norkko *et al.* 1999) and related this to possible sediment generation and delivery under the various land use scenarios using computer simulation modelling (Cooper *et al.* 1999). An important component of this research was also the modelling of estuarine processes to enable prediction of the locations within the estuary where the sediment would be deposited particularly during storm conditions (Green and Oldman 1999). The summary of findings from the NIWA report on ecological risk was that: *“All rural intensification options in the Okura watershed pose a risk to the ecology of Okura estuary due to sediment runoff from earthworks. Applying sediment control strategies can reduce these risks. If the level of risk that is considered ‘acceptable’ is defined then the sediment control strategies needed to achieve this level of risk can be specified”*

(NIWA 1999, cited in Beca Planning 2000:p11).

In September 2000 Beca Planning prepared a report for the local councils on the implementation risks (that is the risk of failing to implement) associated with lower ecological risk, alternative land-use scenarios for the Okura Watershed. Of the original 12 scenarios only 3 were considered serious alternatives in terms of ecological risk.

North Shore City Council in 1998 began to apply integrated watershed management methods to the development of a Structure Plan (Figure 3) for the urbanisation of the watershed adjacent to Okura i.e. that of Vaughans Stream, Long Bay (Hughes and Herring 2001). The land use strategy plan shown in Figure 3 was part of Variation 64 to the North Shore District Plan.

In late 2000 Worley Consultants/Meritec and Bioresarches Ltd. were contracted by North Shore City Council to produce Comprehensive Stormwater Watershed Management Plans for the six southern subwatersheds of the Okura estuary (North Shore City Council 2000).

‘Low Impact Urban Design’ (LIUD) concepts for new urban developments as outlined by Shaver (2000), which operate within a watershed context, were applied. Objectives include increasing residential densities in the lower reaches of the watershed, and retaining considerable areas of open space and indigenous vegetation in watershed headwaters and along stream riparian zones without having to reduce the total number of residents that could be accommodated within the development. Thus intensification of parts of the development and retention of the natural character in other parts would substantially reduce the total impervious area within the watershed reducing proportionately the volume of stormwater generated. (The relationship between impervious cover and the biological quality of receiving water ecosystems is discussed later in this paper.) This pattern of development

would also protect the most erosion prone land thereby reducing the generation of fine sediments likely to be transported to receiving waters.

Ongoing decisions by the Council on the layout of the Structure Plan have been and will be strongly influenced by community consultation on development options. It was the wish of the community to retain maximum areas of open space and vegetation and to minimise the impact of the development upon receiving marine recreational waters and contiguous regional parkland. At the time of writing the Structure Plan is not yet operative and is subject to further change. Variation 64 has two stages the first of which included policies, objectives and the land use strategy (indicative zones only as shown in Figure 2). At the time of writing, specific methods for achieving the policies and objectives, including application of Low Impact Design techniques, are still under development and have yet to be commented on by the public. It is therefore too early, to assess the success of applying an integrated watershed management approach that includes LIUD.

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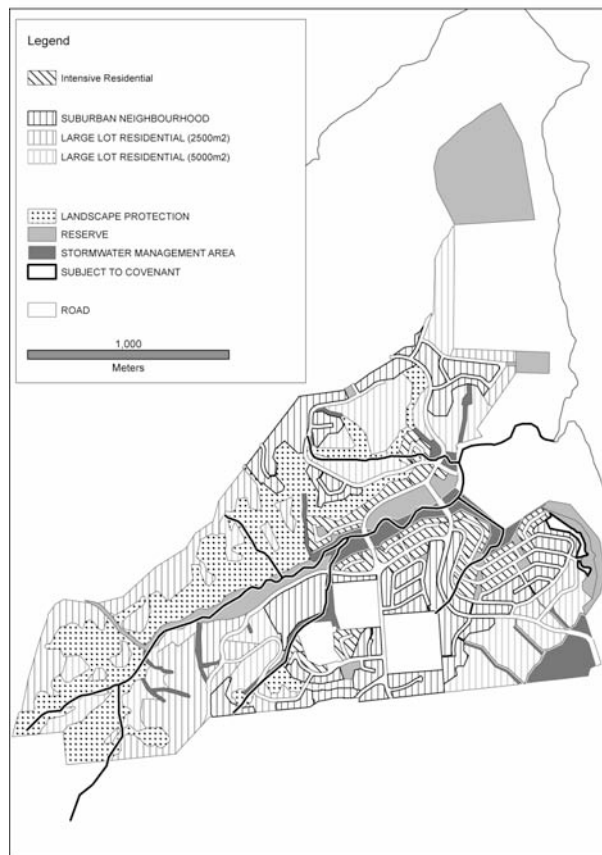


Figure 3. Draft Structure Plan for Vaughans Stream catchment, Long Bay. Map shows proposed uses not yet adopted by North Shore City Council.

### **A City Addresses Drainage, Ecology and Culture**

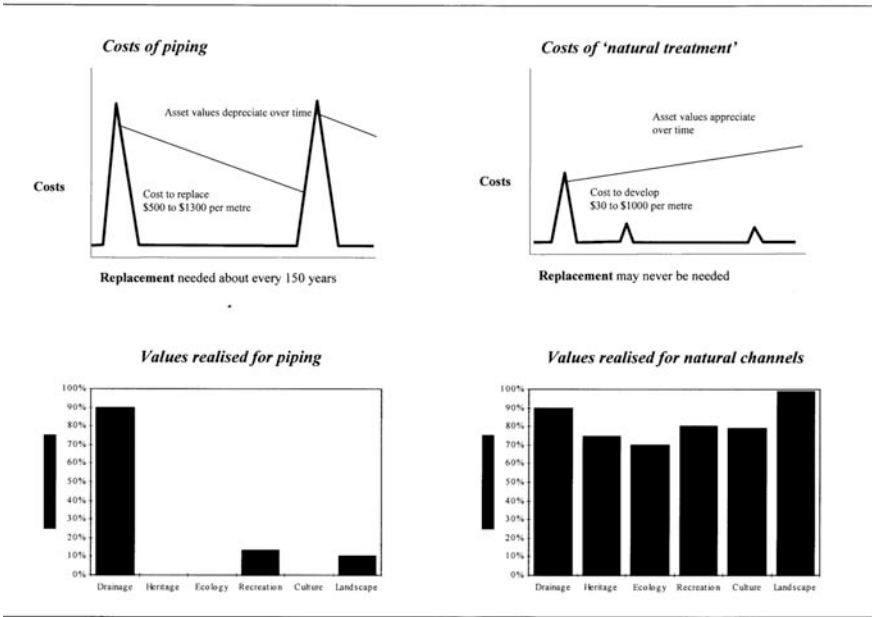
Initiated in 1996, Christchurch City Council's (CCC) Waterways and Wetlands Asset Management Strategy (WWAMS) (CCC 1999/2000) demonstrates the opportunities for integration that become possible when the traditional internal divisions of an institution are overcome. Drainage engineers, ecologists, planners, park managers, and water supply staff, traditionally been segregated into separate Council departments, worked together to solve common issues, with consequent gains in ecology, landscape, culture, heritage, recreation, drainage, groundwater recharge, and long term drainage cost reductions (Figure 4).

The 1996 'Natural Asset Management Plan for Christchurch's Waterways and Wetlands' introduced a values based approach to incorporate the non-drainage categories noted above, and the notion of investing in achieving sustainability over a defined period. The two main activities identified for achieving sustainability were 'restoration' and 'protection' of natural values, with the Council accepting these principles and agreeing to an additional NZ \$0.5 million per year extra expenditure. General restoration and protection needs were identified, based on asset categories (CCC 1999).

As Christchurch is built on a swamp the most efficient way of managing water flow is to work with the consequent ecological processes rather than against them. This runs counter to the approach previously adopted, of large drains and flood control. However, the new approach is hampered by practical restrictions, including opportunities to introduce the new ideas. The Waterways and Wetlands Team (W&WT) tries to use these features to guide designs for both retrofitted and greenfields developments. However, between 1998-99 and 2001, only 5.2 km of riparian and wetland margins had been protected through land acquisition or covenant, and over the last four years, 7.2 km of river margins had been restored. Yet the Council reports that even this modest work has resulted in 'dramatic' increases in whitebait spawning in some smaller waterways, and increases in native wetland birds (Heremaia 2001).

Part VIIA of the New Zealand Local Government Amendment Act 1974 requires local authorities to prepare a long-term financial strategy for asset management. This includes clearly defined costs and benefits. The City's Water Services Unit (which includes the W&WT) administers both the Waterways and Wetlands Natural Asset Management Strategy (the natural component) and the Utilities Asset Management Strategy (pipes, pumps and channels etc). Each strategy proposes a preferred asset condition and identifies the costs of achieving that condition. 'The strategy for waterways and wetlands shows that it is possible to create a sustainable waterway network within about 40 years at little additional cost to the current maintenance and development budget. All urban stormwater would then be conveyed via natural streams. This is an alternative to the piping of waterways, which requires regular financial inputs to renew assets' (W&WT, c2000).

Figure 4 A comparison between a long-term strategy for managing utilities (costs of piping) and one for waterways and wetlands (costs of natural treatment). In the past, these may have been treated as separate cost items; combining them provides potential advantages not previously apparent (CCC 2000).



The different approaches to a combined drainage-natural asset management strategy include:

- Low profile street drainage systems: Here street side beautification is combined with depressions or swales where street runoff flows over flush edges or curbs into grass or other vegetation that acts as a filter for sediments and contaminants.
- Reconstituted waterways: This involves the re-establishment of wetlands and replacement of deep straight channels with more natural stream meanders (Figure 5). If done on a large scale this can reduce water flow rates, increase the streams capacity to store water, reduce the magnitude of peak flood, and act as a buffer against drought. In addition sediment and other contaminants can be removed by the vegetation thereby improving water quality. The vegetation planted (Figure 6) creates recreational environments complimentary to existing reserves.
- Wetland restoration as at Travis Swamp (Figure 7). This was previously a farm, and is being returned to its original lowland freshwater wetland state. A restored naturalised stream links the wetland to the nearby river, forming a 'green corridor' with pedestrian access, providing both recreational and biodiversity value. Reconstituting Travis Swamp involves both dredging out ponds and channels, and revegetation. As of January 2000, 53 species of birds, including 31 native species, had been recorded at the wetland (Travis Wetland Trust and Christchurch City Council 2000) which also contains an estimated 600-900 invertebrates, 83% of which are endemic (MacFarlane *et al.* 1999).

Figure 5 The Naturalisation of Streams in Christchurch Includes the Restoration of Stream Meanders.



Figure 6 Part of a restored stream in Christchurch that has been revegetated.



Figure 7 Travis swamp in Christchurch after ponds and channels have been dredged out and the vegetation restored.



Among the practical difficulties of implementing an integrated management process is identifying which agency or section funds what activity. The Council notes that while such tools as reserve contribution in greenfields developments can be used, if the activity also contributes to such things as stormwater mitigation, judgement is needed to decide the extent to which contributions offset these costs. This also applies to where low-density housing is being replaced by higher density development, with a consequent loss of private green space. Overall, the majority of funds will continue to come from rates, although given the more holistic, values-based approach, the Council notes it may be appropriate to review the rating area (the Land Drainage District is currently 65 per cent of the Christchurch District Area) (CCC 1999).

In terms of how the innovative approach was initiated, meetings with Christchurch City Council Waterways and Wetlands Team members suggest the primary reason was the individuals who happened to be involved. In other words, the innovations were not driven by any legislative or regulatory requirements. On the other hand, it was necessary to have legislation and regulation that (with some imagination) did not prevent an integrated approach.

As noted, while existing development has meant that space is not available to reintroduce waterway systems, the ecological benefits can be disproportionately great. Firstly, this is because the ecological impacts of shifts in hydrology can be underestimated. Flow rates and patterns are key to determining not only flow conditions in main channels but also the presence of microniches such as ponds, riffles, gravel beds and quiet shaded places in bank vegetation. Flow variability, including the magnitude and duration of extreme flows, are important characteristics of stream, wetland and estuarine systems. Reconstituting previous hydrological characteristics, or recreating approximations of natural systems, can result in:

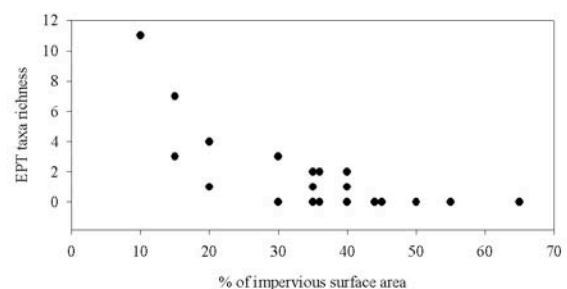
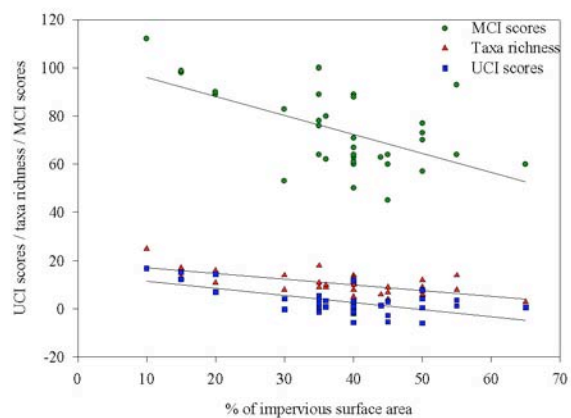
- Reduction in unusually high and low flows; a reduced likelihood of contaminants being concentrated due to lack of dilution during summer low flows; less likelihood of undesirable water temperature rise; the return of ponding, creating temporary or semi-permanent habitat; and increasing flow rates, favouring swimming species and the aeration of eggs on the stream bottom.
- Reintroducing wetland flooding patterns, complementing the cycles of riparian plants and associated animal species, and resulting in greater in-stream and associated terrestrial biodiversity.
- Reducing unwanted downstream sedimentation and deposition of contaminants (van Roon and Knight in press).

While generally positive, some changes may be less acceptable to the local community. Upstream flooding is one mentioned above. Another is the increase in debris in streams and wetlands. This debris from riparian vegetation is a natural part of the habitat and food input to streams, but may be seen as unsightly to locals. There are also implications for private landowners, who might see restoration as a threat to existing land use and access along stream margins. In addition, the emphasis being placed on using native plants as part of the revegetation component of the project is being seen to threaten the existing 'garden city' status of Christchurch. Hence the importance of working with communities on a range of restoration issues (see, for example, Christchurch City's Avoca Valley Stream restoration programme - Lucas Associates and Christchurch City Council 1998) and the need for an education strategy based on the following: initiating awareness; fostering communication and understanding; promoting active participation; and then requiring communities to take on the role of guardianship (Heremaia 2000).

Also beneficial is the integration of steps to reduce hard surfaces and consequent peak-flow stormwater run-off entering the drainage system. This is because from a stormwater perspective, the reconstitution of wetlands and waterways is still a down-the-pipe mitigation measure. Reducing run-off intensity and associated contaminant load at the point where they are created - further upstream or up-watershed - improves the capacity of whatever stormwater system is in place. Narrowing roads and introducing vegetation to filter out contaminants helps address the problem at source.

Ecologically, New Zealand studies of stream fauna show that as the percentage of impervious surface increases, there is a general decrease in the number of taxa and, more particularly, the number of sensitive native species surviving in streams (Allibone 2001; Figures 8). Hence reducing percentage hard surface cover significantly complements efforts to reconstitute natural waterways and wetlands.

Figure 8. Relating the percent of impervious surface in a watershed to the biodiversity of selected invertebrates in a stream. Conversion to hard surfaces is associated with a range of physical and chemical changes in waterways, including increased flood peaks and sediment and pollutant loads. The ecological impacts can be measured by changes in the make-up of in-stream animal communities. These graphs summarise measures of invertebrate community health for 35 urban Auckland stream sites, and show significant negative regressions. (a) MCI: Macroinvertebrate Community Index; UCI: Urban Community Index. (b) EPT: the relative numbers of the larvae of the insect species Ephemeroptera, Plecoptera and Trichoptera, which are sensitive to certain kinds of physical and chemical change. (Source: Allibone, 2001).



## **RURAL**

### **Waterway Pollution Leads to Riparian Reafforestation –the Whaingaroa case**

The problems most closely associated with land during the past 40 years in New Zealand have included the degradation of soils by erosion, acidification, contamination, compaction and loss of structure. In addition, there has been ecosystem damage via the silting up of streams, rivers (Boulton *et al.* 1997; Quinn *et al.* 1997) and estuaries (Green and Oldman 1999; Cooper *et al.* 1999); drainage of wetlands and peatlands; algal blooms and dense growth of aquatic weeds resulting from nutrient rich run-off water; pests and weeds. The removal of indigenous forest to make way for pasture has left some 10 million hectares of North Island hill country at risk from both sediment and nutrient loss (MfE 1995b).

Given these issues “have not always been recognised as matters to be concerned about” (MfE 1995a) there was a strong but unstated implication that the balance between economic, social and ecological issues is skewed against the ecological: some catching up was needed. In 1995 the New Zealand Ministry for the Environment produced a Sustainable Land Management Strategy (SLMS) (MfE 1995b). The Strategy identified the priority issues needing attention as being water quality, protection of elite soils, hill country erosion, ecological decline and drought potential. Another issue flagged in 1995 and resurrected in the late 90s was the continuing headache of what to do about cumulative impacts.

The objective of the SLMS was to ensure “all the key players in this area are working toward a common goal, as quickly and cost effectively as possible” in order to improve environmental health, maintain productivity and protect the clean, green marketing image for export and tourism promotion. Central to the strategy was land management responsibilities resting primarily with the landowner or manager.

The Whaingaroa Environment is typical of the New Zealand landscape, comprised, as it is of a high proportion of pastoral land (sheep and cattle), remnants of indigenous habitats, areas of exotic forestry, and small towns. Over the last century indigenous vegetation has been cleared from more than half the catchment (watershed) of 525 km<sup>2</sup>. The lack of vegetation on the steeper parts of the catchment means that they are prone to slips (EW, 1998). Whaingaroa (Raglan) Harbour (Figure 9) covers 33 km<sup>2</sup>. There are 220 kilometres of coastline on the Whaingaroa Harbour, and as of 1999 little of it was vegetated, fenced or legally protected in any way (WHC 1999).

Figure 9 An Aerial View of Whaingaroa Harbour (CNES copyright)



The Whaingaroa Harbour Care (WHC) group was formed in 1994 as a result of concern over changes observed in the harbour ecosystem and siltation of local waterways. Leading members of WHC believed that several factors were contributing to changes in the physical, chemical and biological environment of the harbour, which in turn may have contributed to the decline in populations of harvestable species and a loss of amenity previously associated with the harbour. They noticed the deposition of sediments on harbour flats that were once relatively clean sand. There were recollections of crystal clear waters jumping with prolific numbers of fish. There is a loss of amenity and a threat to the *mauri* (life force) of the harbour associated with these changes. The once abundant biodiversity of this environment has been reduced by the clearance of indigenous forest, the degradation of streams and harbours by pastoral runoff and waste discharges, loss of riparian and instream vegetation, over-harvesting of popular indigenous species, and the destruction of important habitats.

Whether there is a direct causal relationship between the losses of productivity and biodiversity, and the observed physical changes, is impossible to determine without historical scientific data to show

population trends. Concerns about these issues led to the establishment of groups like WHC and another known as Whaingaroa Environment (WE).

There was local scientific evidence emerging at this time, of the impairment of biodiversity (based on an index of biological integrity (Quinn *et al.* 1997)) in pastoral streams compared to native forest streams. Whaingaroa streams, once clear flowing, typically had abundant koura (freshwater crayfish) and native fish like banded/ giant kokopu. Today these streams are turbid and are likely to be dominated by more sediment tolerant species such as eels. Questions began to be asked as to what were the causes of this degradation and what measures could be taken to avoid or remedy this. Cattle trampling, sediment and nutrient run-off from pasture, bank de-vegetation, weirs, culverts, dams and road crossings all disturb pastoral streams lowering instream biodiversity. Rock clusters are of critical importance on streambeds for protecting invertebrate communities (Bigg *et al.* 1997). A decline in the formation and stability of these rock clusters is likely as a result of all the above pastoral activities. The stream can be protected from these activities by fencing and the maintenance of riparian vegetation. The justification for riparian vegetation retention or restoration comes from a considerable volume of NZ research (McCull1978, 1982; Wilcock 1986; Smith 1989; Rutherford *et al.* 1987; Quinn *et al.* 1993, Collier *et al.* 1995, ARC 2001)

At Whaingaroa (Raglan) community volunteers have been strongly motivated by this evidence. They decided that extensive riparian planting of the catchment's streams was likely to be the most practical and effective contribution they could make to reversing the adverse effects of pastoral farming. These volunteers, coordinated under Whaingaroa Harbour Care, have been responsible for the fencing and riparian planting of 350 – 400 kilometres of stream and harbour edges. Community wage-workers have been employed in the WHC plant nursery to propagate and plant out native tree seedlings. WHC has the capacity to plant up to 100,000 trees annually (WHC 1999, Edwards pers.comm. 2001). There are 220 kilometres of harbour riparian zones and WHC anticipate planting 5 kilometres of this each year. WHC expect to take 50 years to complete the task, which should reduce sediment input to the harbour and provide additional habitat for wildlife (WHC 1999).

WHC finished planting the most visible areas first, as a means of educating the community. These areas included high priority publicly owned lands such as estuarine strips and esplanade reserves. The group then turned its efforts to the most impacted privately owned areas adjacent to streams, such as immediately downstream of dairy shed discharges, and unstable high country lands in the upper catchment (watershed). WHC was assisted by another community group 'Whaingaroa Environment' in gaining the cooperation of farmers.

The WHC has been aided in coastal edge riparian work by a requirement in the Waikato Regional Coastal Plan (EW 2001) for the fencing of riparian areas to exclude stock. The fact that planting is expected to take so long to complete adds to the urgency to develop simultaneous methods for reducing farm-generated pollution at source while continuing with riparian planting. For example, in addition to riparian planting a few farmers are planting unstable pasture areas. In other parts of the Waikato Region farmers have retired up to 20% of their farms without loss of income (Ritchie pers.comm. 1999). At Wainui Reserve, Whaingaroa, approximately one third of the farm (the steeper parts) has been retired from pasture and the number of stock units has been increased (WHC 1999). Farming effort is concentrated on the flatter less erosion prone land.

The problem of erosion control on high country pastoral lands of the Whaingaroa catchment is likely to be very similar to that in the adjacent research farm of the Crown Research Institute AgResearch at Whatawhata. At this site scientists have designed a ten-year pasture catchment (watershed) study to investigate the relative importance of various sources of sediment reaching waterways, such as from tracks, slips and sheet erosion. Pastoral catchments in Whatawhata yield 230 tonnes/km<sup>2</sup>/year of sediment whereas Whaingaroa catchment areas covered in indigenous forest yield 45 tonnes/km<sup>2</sup>/year (Quinn, pers.comm. cited in EW1998).

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## **Dairy Farming Expansion- Curtailment by Nitrogen Limited Eutrophication of a Pristine Lake Ecosystem**

At Lake Taupo, an innovative approach using community values to shape strategic planning and lake management is being trialed, under the banner '2020 Taupo-nui-a-Tia'. Taupo is the New Zealand's largest lake, at around 620 km<sup>2</sup> with a mean depth of 95 metres (Figure 10). It is oligotrophic, with unusually clear, blue water with a visibility of around 14 metres due to there being little sediment or phytoplankton (Gibbs 1998; Edgar 1999; Vant and Huser 2000). Taupo is under threat of increased nutrient loads through land-use changes.



Figure 10 The Catchment (Watershed) of Lake Taupo (Environment Waikato)

In many fresh water systems around the world, phosphorus is in short supply while nitrogen is available in excess. It is the ratio between concentrations of phosphorus and nitrogen (P:N) that influences plant growth. So even with extra N, plants are limited by the amount of P. Add extra P to the system, and this stimulates plant growth.

Unusually, New Zealand lakes do not often have large amounts of nitrogen (Vant and Huser 2000). In addition, phosphorus levels are relatively high in many lakes in the North Island's central volcanic plateau, due to geochemical leaching of phosphorus from the pumice soils (Timperley 1983; Vant and Huser 2000). So Taupo has had plenty of phosphorus

available, but too little nitrogen for phytoplankton to bloom. Combined with its low-nutrient status, this means the lake is unusually sensitive to shifts towards agricultural land use.

The natural tussock grassland and native forest of the catchment (watershed) started disappearing in the 1840s, and much has been replaced by pine and pasture. Then from about 1970, government and private landowners began developing the land in the northern and western parts of the catchment. By 1996, about 22% of the land was in pasture, and lifestyle blocks<sup>1</sup> also appeared (Petch *et al* 2001). Thus while current nitrogen loads to the lake remain low relative to other lakes (about 3-4 kilograms of nitrogen per hectare per year (kgN/ha/yr) compared to mid-1970s inputs to nearby eutrophic Lake Rotorua of 13 kgN/ha/yr), it is estimated this is still 20-30 per cent higher than pre-development levels (Vant and Huser 2000; Petch *et al* 2001).

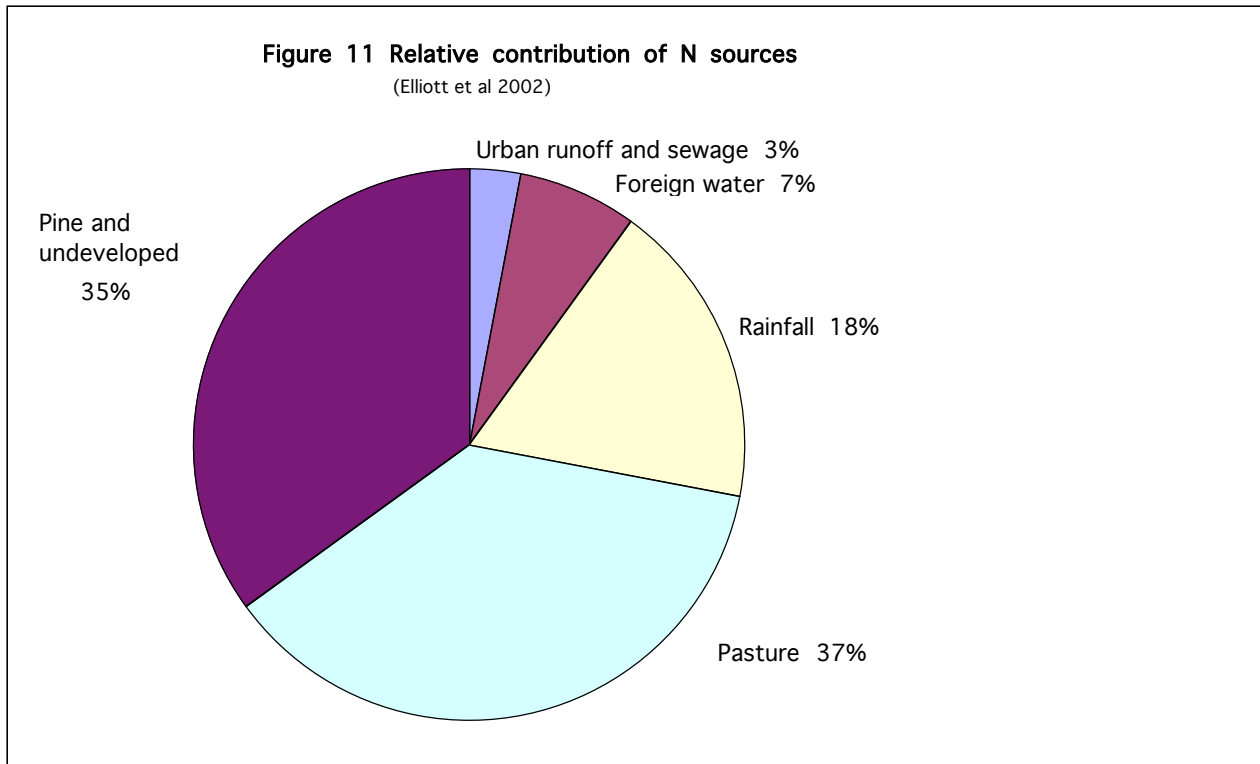
In addition, there is a delayed impact from additional nitrogen. Nitrogen is stored in soil and groundwater, entering the lake only slowly. Therefore it can cause changes to water quality over as much as 30 years or more. Groundwater can by-pass riparian strips which normally remove much of the nitrogen from surface flow (Vant and Huser 2000; Petch *et al* 2001).

Changes are already apparent, with an approximately seven per cent decline in lake water clarity from the 1970s (Edgar 1999) and an increase in phytoplankton. Phytoplankton biomass increases in direct proportion to increasing nitrogen concentrations (Vant and Huser 2000). These changes indicate a decline in overall water quality (Gibbs 2000). Algal slimes and blooms of filamentous green algae are also occurring, stimulated by sewage wastewaters from local lakeside communities (Petch *et al* 2001). The relative contribution of nitrogen to the lake is given in Figure 11.

<sup>1</sup> Lifestyle blocks are small 'farmlets', usually stocked or cropped at medium or low intensity.

The concentration of nitrogen per land area from undeveloped native forests and pine is about 2.5 kgN/ha/yr, while pasture produces 5-15 kgN/ha/yr (Vant and Huser 2000; Elliott *et al* 2002). So at 620 km<sup>2</sup>, pasture contributes at least the same amount of N, and possibly three times as much, while covering only half the area of native forest (1,180 km<sup>2</sup>). The 'foreign' water is diverted from other catchments (watersheds) via a hydroelectric development scheme at the southern end of the lake (Elliott *et al* 2002).

But dairy farming, depending on stocking rates per hectare, can yield 20-50 kgN/ha/yr (Vant and Huser 2000; Elliott and Stroud 2001). The drive for dairying in the Taupo catchment has been strong,



with mid-1990s conversions of 6,400 hectares in land to dairy farming creating \$14.5 million extra total output, \$5.25 million in extra value added, \$2.3 million extra in household income, and 112 extra jobs (MAF 1997). The concern is that past conversions have already increased the nitrogen load, and further conversions will increase the load disproportionately. If all the potentially convertible land area (between 100 and 250 km<sup>2</sup>) shifted to dairying, the nitrogen levels in the lake would increase by about 20-60 per cent, stimulating a roughly similar increase in phytoplankton and a decline in visibility of 20-40 per cent (Vant and Huser 2000; Petch *et al* 2001).

The question now is whether the community voluntarily restricts farming intensification. The prospect of voluntary change is limited (Petch *et al* 2001) because there is a direct cost to existing farmers in reducing intensity (Ritchie 1999), and an opportunity cost for those either wanting to convert land to dairying, or planning to sell potentially convertible land. Legally, Environment Waikato could exercise powers under s30 of the 1991 Resource Management Act 1991, which allows regional councils to control the use of land for the purpose of maintaining and enhancing water quality. But regulation is difficult because the discharges are diffuse, cumulative, hidden and long term. The time lag between cause and effect means there is little immediate and concrete evidence of the environmental benefits of controlling sewage or farming (Petch *et al*. 2001). Also, landowners or users could protest under s85 of the RMA that restriction could limit reasonable use of land. This includes land under Maori (First Nation) trust ownership, and trustees see dairy conversion or intensification as a way of generating much-needed cash flow.

On the other hand, the lake is spiritually important to Ngati Tuwharetoa (first nation tribe), and dairying is a relatively minor component of Taupo's economy, which is dominated by tourism, forestry and urban activities. These activities are either reliant on good lake water quality, or contribute little extra nitrogen loading above what was entering the lake prior to development (see Figure 11).

At the time of writing, the Taupo community was considering four options (Environment Waikato c2000). One involves freezing nitrogen loads at present levels and accepting a decline in water quality (Option 3). Another involves freezing then reducing nitrogen loads below present levels, to keep water quality at today's standards (Option 2). The third suggests improving water quality through stricter controls (Option 1). The fourth is a 'do-nothing' option. Environment Waikato considers it feasible to reduce by one-fifth the amount of human-sourced (manageable) nitrogen flowing into the lake (a little over 40 per cent of the total, remembering that most nitrogen entering the lake is from natural sources). This would meet the goals of Option 2 (Vant pers comm. 2002).

There is also an issue of government (that is, wider society) responsibility, given that it was the subsidies of the now defunct Department of Lands and Survey that encouraged conversion to pasture in the first place. Government land still accounts for about 18 per cent of the catchment total, and converting this to forestry would reduce manageable nitrogen loads by about 10 per cent. The remaining 10 per cent could be met by buying up about half the remaining non-Maori privately owned land and converting that to forestry, too. This approach would still require restrictions on the scale of intensive farming around Taupo.

## **Conclusion**

The New Zealand cases described in this paper demonstrate how community aspirations for aquatic ecosystems to be retained in, or restored to, good ecological and aesthetic condition can influence land use options, site plans and management within river basins (watersheds/catchments).

While ecological capacity should be a primary driver of resource management decision-making (IUCN 1980; Lucas, 1980; OECD, 1997; Rees 1999) the dominant approach tends to see ecosystems as one of a raft of 'holdings' to be traded off to give a net increase in asset value (Pearce 1998; Rees, 1999). Such a balance lends itself to trading off down to ill-defined 'biophysical bottom lines', rather than 'trading up' to enhance ecological values.

It is essential to clearly identify these markedly different ways of incorporating ecological values into resource management decision making. Working with ecological processes is becoming more accepted in NZ, but is still limited to cases where motivated volunteers, researchers or local councils focus on unique critical ecological needs and draw in others to develop an integrated process.

Demand for local land uses is market driven. In order to effectively conserve and rehabilitate land and water biodiversity, the ecological potential and capacity of catchments needs to be assessed and balanced against market demand for products. The balance between responding to market place signals and working with ecological restrictions needs to shift towards the latter. This is happening in some areas already as shown by the case studies above. What is being proposed in some cases such as Christchurch or Whaingaroa is, in effect, ecosystem rehabilitation. This may mean existing 'normal' land use patterns need to change if ecological recovery programmes are to succeed. The economic and social implications of changes in land use practice needs to be extended to anticipate these impacts. This is in fact what is happening in Christchurch as the City Council has come to realise that a change to the naturalisation of waterways and riparian lands can be achieved without loss of drainage function, at no additional cost, and with substantial gains for amenity and recreation.

What are the implications for communities such as Whaingaroa, Christchurch, Taupo or Long Bay? In order for them to halt and reverse ecological decline and protect biodiversity, they need to account for:

- The national and global economic pressures driving local land use decision making. Working with ecological processes implies shifting where costs and benefits fall, that is, there may be greater public benefits and higher short-term private costs. There are also opportunity costs to consider. For example, weighing up high value urban land (coastal land is extremely valuable in NZ) development against ecosystem values. There may also be opportunity costs of forgoing dairy conversions to protect a lake. Such thinking is relatively new in NZ, where colonial attitudes of the past 150 years favoured productive value as the primary driver for land-use decision-making.
- Whether these pressures override local voluntary attempts to reverse ecological degradation and hence biodiversity loss.
- The influence of economic drivers on shaping local resource management regulations.

Above all there has to be a greater appreciation of the time factor and time delays that are part of ecological change. There is an under-appreciation of the time element in ecological changes and how the planning and management process can address these. Traditionally, planning processes have been short term and responsive to political electoral cycles rather than the time scale involved with many natural processes.

These issues need to be clearly identified in order to better assess both rights and responsibilities for land owners, the extent to which compensation is due, and the extent to which moving toward a more ecologically-based assessment of suitable development is realistic within a global economy. Such identification will also help establish where regulation should enforce change while accepting that voluntary shifts in behaviour are preferred and in some cases necessary for success.

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