Proposed Marlborough Environment Plan

Response to Minute 30 of the Hearing Panel

Drainage Channel Network – Sediment Removal

From: Peter Hamill

1. The Councils Drainage Network, as identified in the Proposed Marlborough Environment Plan, includes a number of rivers. Defining which specific parts of the Draining Network are rivers is not necessarily straightforward and has been interpreted in number of different ways.

2. The Rivers Department and the Environmental Science and Monitoring (ESM) Team of the Council have different views over which watercourses in the Drainage Network are rivers under the Resource Management Act (RMA).

3. The RMA defines a river as a continually or intermittently flowing body of fresh water; and includes a stream and modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal).

4. The difference between the two points of view comes around the definition of an artificial watercourse and the inclusion of a farm drainage channel.

5. When European settlers arrived in Marlborough some 170 years ago the lower Wairau Plain was a large wetland dominated by flax and raupo. Since that time the wetland has been systematically drained by the development of a drainage network to what we see today. The drainage network is all that is now left of the wetlands. The Drainage Network channels are intercepting the natural groundwater that once sustained the wetlands and are conveying the water away in a modified watercourse. It is the ESM teams view that because the channels are diverting natural water flows they are modified watercourses and therefore rivers under the definition of the act. The Rivers Section views large parts of the drainage network as artificial constructed watercourses or farm drains and therefore are not considered rivers.

6. There are a total of 254 identified channels in the Drainage Network. From my knowledge of the Drainage Network there are 196 named channels that should be considered to be rivers. The 61channels that are artificial drainage channels that are not conveying natural groundwater and therefore are not rivers in my view are show in Appendix 1.

7. Notwithstanding whether the watercourses are drainage channels or rivers, the Drainage Network provides habitat for indigenous aquatic species including species rarely found in Marlborough such as giant kokopu.

8. The Drainage Network is the home to a large number of eels (predominately shortfin). A rule of thumb, in terms or numbers that I have observed over the years of looking at these watercourses, is that you can expect to find at least 1 eel per

linear metre of drainage channel. With the Drainage Network that I consider to be a watercourse being approximately 150km long this means that approximately one hundred and fifty thousand eels live in these waterways at any point in time. The drainage network is also an important habitat for inanga (part of the whitebait catch), upland and common bullies and koura (freshwater crayfish)

9. In 2002 the Council contracted CAWTHRON to carry out an assessment of the Spring-fed streams on the Wairau Plain (attached). The assessment showed that the majority of the watercourses (the Drainage Network) on the Wairau Plain were medium or above, in terms of ecological value.

10. After this report was produced the methodology of clearing out the Drainage Network was adapted so that the cleaning out of nuisance aquatic vegetation and sediment were carried out using a different methodology. The removal of the nuisance aquatic vegetation was change to use a tined bucket (see photo 1) rather than a solid bucket. The tined bucket is essentially like a large comb that catches just the vegetation and lifts it out leaving the sediments behind. The bucket allows eels that are in the vegetation to fall through the tines and back into the watercourse. Leaving the sediments behind is important because that is where the eels are living during the day before coming out into the water column at night to feed.

11. In 2016 a follow up assessment of watercourses on the Wairau Plain (attached) was conducted by NIWA to determine and changes over time. The report shows that in general there has been a general deterioration in the ecological condition of the watercourses since 2002. The 2016 report also stated that the ecological values of watercourses on the Wairau Plains were limited by modified channels, heavy siltation and excessive in-channel vegetation dominated by invasive weeds.

12. The Drainage Network almost entirely made up of watercourses that form through the interception of groundwater and have very small flat catchment areas. As a result the sedimentation that enters the system is not coming from erosion of hills and mid slope failures, but from bankside collapse and inputs from subsurface drainage. This means that the volumes of sediment that end up in the waterways are of relatively small volumes.

13. The removal of sediment from the Drainage Network needs to be managed very carefully to ensure that the channels are not deepened any more than they currently are. If the channels are deepened it means that more ground water is intercepted which in turn reduces aquifer pressures. A deeper channel also increases the risk of bank collapse starting the whole cycle of the need for sediment removal again.

14. According to Geoff Dick the Senior Rivers Engineer the sediment removal of any part of the Drainage Network is limited to once every approximately 10 years to ensure that the deepening of the channels does not occur.

15. When sediment is removed from these waterways there is a dramatic impact on the instream life. Essentially the habitat that the aquatic life has been relying on, is totally removed and a bare channel with no habitat is all that remains. Until sediments reform in the bed and vegetation or instream debris re-establishes itself the watercourse becomes a very limited habitat. Any animals that happen to escape of find their way back into the water will have to relocate to another part of the network to find shelter, cover and food.

16. A study of the impacts of herbicide and mechanical excavation carried out in Marlborough (Young et al 2004) (attached) found that while some eels that were removed from the watercourse during the process of removing the sediment by mechanical excavation would have survived by finding their way back to the water by themselves, the majority would not survive.

17. Unfortunately eels and other fish and animals do not have an innate ability to sense water and only eels have the ability to travel any distance across wet surfaces. All species other than eels that are caught in the sediments and placed on the bank will die. The eels that do make their way back to the water when sediment is retained on the banks only make it through the luck that they emerged on the down slope side of the sediments and moved down slope to the water. Any eels that emerge from the sediments on the opposite side of the pile of sediment away from the watercourse do not know to go over or through the sediment to find water and end up dying along the edge of the sediment. If the sediment removal occurs on a typical hot sunny Marlborough day even those eels that emerge on the downstream side of the sediments retained on the banks will dry out and die before they can make it back to the water. The eels slime sticks to the dry soils and stops them being able to slide across the surface of the ground. Manual recovery of the eels and physically placing them back in the water is required on all occasions.

18. Young et al 2004 found that it took over 6 months for the habitat of a watercourse to return to the state that it was prior to the excavation.

19. The stabilisation of the banks plays an important factor in reducing the input of sediment into these systems. Riparian plantings would assist with the bank stabilisation while also shading the watercourse and therefore reducing the vigour of the nuisance aquatic vegetation. Riparian plantings however make access to the waterways by excavators and spraying equipment very difficult which in turn adds to the expense of maintaining the network.

20. Very few of the watercourses in the Drainage Network have a water depth of more than 2m. The lower reaches of Spring Creek and the occasional groundwater emergent zone are the only areas that would trigger this standard.

21. It is my view that the removal of sediment form “rivers” in the Drainage Network as identified in the pMEP will have an adverse effect on instream ecology and should be minimised.

22. The small volumes of sediment entering the Drainage Network means that sediment removal is rarely required and therefore the impact on the ecological values may be so infrequent that a permitted activity is an acceptable option. In order to minimise the ecological impact of sediment removal it is my view that the removal should only occur when water trigger level are met that indicates that issues in terms of drainage will occur, rather than on a scheduled programme. (In coming to this conclusion I have not taken into account any operational considerations.)

Photos

Photo 1 - Tinned bucket that allows eels and other life to fall back into the river.

References

Hudson, H.R.; Harding, J.S. 2004: Drainage management in New Zealand: A review of existing activities and alternative management practices. Science for Conservation 235. Department of Conservation, Wellington, New Zealand.

Young, R.G.; Keeley, N.B.; Shearer, K.A.; Crowe, A.L.M. 2004: Impacts of diquat herbicide and mechanical excavation on spring-fed drains in Marlborough, New Zealand. Science for Conservation 240. 50 p

Appendix 1

Artificial Channels

1. Caseys Drain B
2. Cloudy Bay
3. Willies' Drain
4. Industrial Drain
5. No Name – 196
6. Moorlands Outlet
7. Dr S
8. Stuart St
9. Dodsons
10. Wakefield St
11. Rapaura Rd
12. Campbells
13. Upper Dillons
14. Dr D 2
15. Dr V
16. Whites Drain East
17. Whites Drain
18. Wallace Overflow
19. Wakefield St
20. Vickerman St
21. Sutherlands
22. Steves Drain
23. Snowdens
24. SH1 Roadside
25. Railway
26. Peters
27. Osgoods
28. Nursery Drain
29. Morrisons
30. Moorlands Outlet
31. Miltons Drain
32. Jenkins
33. James Culvert
34. Hollow
35. Hoddie's
36. Hocquards
37. Harvey Rices
38. Harris Drain
39. Glovers
40. Garths

41. Footes
42. Flat Lands
43. Dungys
44. Dr Z
45. DR P
46. DR M
47. Dr K
48. Dr J
49. Douglas No 2
50. De Castro's
51. David St
52. Cresswells
53. Cooper & Morrison
54. Connollys Rd
55. Cloudy Bay
56. Bullet's Drain
57. Boundary Drain
58. Awarua Park
59. Aubreys
60. Airey
61. Adrians

Cawthron Report No. 737

Ecological Assessments of Spring-fed streams on the Wairau Plain

Prepared for

MARLBOROUGH DISTRICT COUNCIL

June 2002

Ecological Assessments of Spring-fed streams on the Wairau Plain

Prepared for

Marlborough District Council

by

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Cover Photo: Murphys Creek: Cawthron, March 2002

EXECUTIVE SUMMARY

The freshwater springs of the Wairau Plain constitute an important aesthetic and cultural resource for the local community. However, apart from some recent work on the ecology of Spring Creek, the habitat value and ecology of these springs is not well known. Due to their connection with the underlying Wairau Aquifer, spring flows are remarkably constant although droughts and floods do have a short-term influence. This report is the first step in deriving an ecological assessment of the Wairau Plain springs.

Twenty four sites were sampled as part of this study. Existing information from 10 sites in the Spring Creek catchment was also included. Statistical analysis of the water quality and physical data from each site indicated that there were four groups of springs. Riverlands Industrial was in a group of its own and characterised by severe contamination with bacteria, nutrients and sediment, very low dissolved oxygen, and a weak connection with the aquifer. A second group (‘red’ sites - Marukoko, Pukaka, Jeffreys, Pipitea Nth, Pipitea Sth) was composed of sites near the coast with tidal influence and thus high conductivity water, high phosphate levels, low bacterial and nitrogen concentrations, and a weak connection with the aquifer. The third group (‘blue’ sites – Riverlands Co-op, Town Branch, Woolley & Jones, Yelverton) also had a weak connection with the aquifer, but low conductivity and relatively high nitrogen concentrations. The largest group of springs (‘green’ sites e.g. Spring Creek, Grovetown Springs, Murphys, Fultons, Roberts) had a strong connection with the aquifer, low conductivity, moderate dissolved oxygen concentrations and variable nitrate-nitrogen concentrations.

Seventy three types of macroinvertebrates were collected from the springs. To a large extent the macroinvertebrate communities present in each spring reflected the water quality and physical conditions found. Riverlands Industrial had only very tolerant types of macroinvertebrates, while the ‘red’ sites had variable, but generally higher quality, macroinvertebrate communities, including some sensitive species such as amphipods. Stream health at the ‘blue’ sites, as indicated by macroinvertebrate communities, was variable with a high diversity of macroinvertebrate types at three of the four sites, but generally few sensitive species. The coarse gravel substrate at Yelverton, a habitat not normally found in lowland springs, was probably responsible for the high diversity of mayflies and caddisflies found at this ‘blue’ site. The quality of macroinvertebrate communities at the ‘green’ sites varied enormously, with relatively poor communities at Sadds and Ganes, and high quality communities at Drain N, Drain Q, Caseys, Kellys, Cravens and the upper reaches of Spring Creek. Amphipods were found at all ‘green’ sites except Sadds and Ganes. Koura were only found at the ‘green’ sites, but were not observed at Doctors, Roberts, Sadds, Grovetown Springs, Murphys or Ganes. An ordination of the macroinvertebrate communities using presence/absence data supported our initial site groupings based on the water quality and physical information. The only real exception to this was the invertebrate community at Sadds, which appeared to be different, and of poorer quality, than that at the other ‘green’ sites.

Forty three different kinds of plants were recorded in, or surrounding, the sites surveyed. Of these, 18 were primarily aquatic, while the remaining 25 were associated with the margins of waterways, or were purely terrestrial plants. Twelve of the aquatic plants were introduced species and included nuisance species such as *Egeria*, *Lagarosiphon* and *Glyceria maxima*.

Six different species of fish were found during our survey of the Wairau Plain springs. These were the native longfin eel, shortfin eel, giant kokopu, inanga and common bully, as well as the introduced brown trout. Lamprey, banded kokopu, yelloweye mullet, giant bully, black flounder and common smelt have also been recorded previously in the Wairau Plain area and may be present in some of the springs. Our observations of two giant kokopu were the first officially recorded

sightings in the Wairau Plain area since 1973. Shortfin eels were the most common species of fish found in the springs. Inanga and common bullies were also widespread, while longfin eels and brown trout were only found occasionally. Fish diversity was generally highest in the 'green' sites, although Sadds was an exception with only two fish species recorded. No fish were found in Riverlands Industrial and, apart from Marukoko, fish diversity at the 'red' and 'blue' sites was generally poor.

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Report reviewed by: Approved for release by:

Dr John Stark, Senior Freshwater Scientist Rowan Strickland, Freshwater Group Manager

1. INTRODUCTION

This report presents the results of an ecological survey of important spring fed streams on the Wairau Plain, and builds on recent studies into the ecology of Spring Creek and its tributaries (Young *et al.* 2000). It documents flora and fauna, along with identifying springs or reaches of springs that are most at risk. Springs are also ranked in terms of their importance and potential habitat value.

A better understanding of spring ecology is needed given increasing pressures that Marlborough District Council have to deal with including: riparian landuses, soil drainage, aquifer effects and consent applications. This is a technical document that will inform the community and enable Marlborough District Council to make management decisions on issues associated with the springs.

The Marlborough Regional Policy Statement recognises the need to maintain or enhance freshwater ecosystems and makes specific reference to the Wairau Plain springs. The Proposed Wairau-Awatere Resource Management Plan controls the damming, taking and diversion of water along with the discharge of contaminants to waterways. It safeguards the natural character of waterways and allows for the maintenance of a network of drains and flood control works.

The Wairau Plain hosts a belt of freshwater springs that represent an important natural and cultural resource for the Marlborough community. These springs appear in various forms from the widely known and appreciated Spring Creek to less well known waterways such as Drain N. Most of these spring-fed waterways rise between the Wairau River and the southern side of Blenheim, in a belt eastward of Hammerichs Road. These springs have generally been modified over the past 150 years to improve agricultural productivity or through urbanisation and today they bear little resemblance to their original natural state. Because the spring belt exists by virtue of the underlying Wairau Aquifer, flows, however, are remarkably constant, although droughts and floods do have a short-term influence. Figure 1 shows a conceptual view of how the hydraulic link between springs and groundwater works.

This report presents detailed ecological assessments for 34 water bodies. This information will provide an essential resource for the community and Council in managing these very special features of the Wairau Plain.

As a result of submissions on the Proposed Wairau-Awatere Resource Management Plan, the Council is committed to developing a riparian management strategy that will integrate issues within the channel and its associated margins.

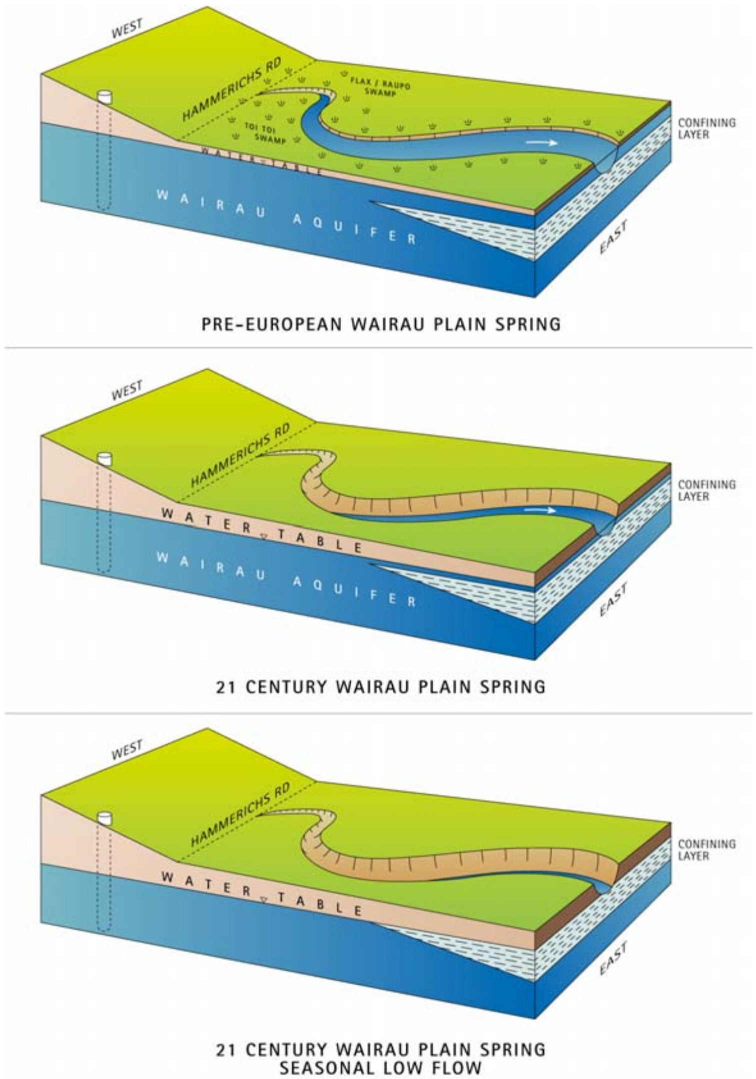


Figure 1 Diagram of the Wairau Plain showing the effect of land modification and droughts on water tables, the Wairau Aquifer and spring flows.

2. METHODS

2.1 Site selection

Seven groups of springs were identified following an initial field tour around the Wairau Plain in January 2002: coastal sand dune springs, large lowland springs, low gradient stagnant springs, Riverlands impacted drains, urban springs flowing into the Taylor/Opawa, rural springs flowing into the Taylor/Opawa, and rural springs flowing into Spring Creek and the Grovetown Lagoon. Representative sites from within each of these groups of springs were chosen and 24 sites were sampled over the week from 18-22 March 2002 (Figure 2). Data reported by Young *et al.* (2000) from 10 additional sites (Tennis Courts, O'Dwyers, Hollis, Ganes, Rapaura, Dentons, Motor Camp, Roses, Collins Bridge, Floodgates) in the Spring Creek catchment were also included in the data analyses (Figure 2). A summary sheet for each site can be found at the end of this report (Appendix 1). Each sheet includes: location map, photo, cross-section diagrams and a brief description of the physical and biological characteristics, as we found them in March 2002.

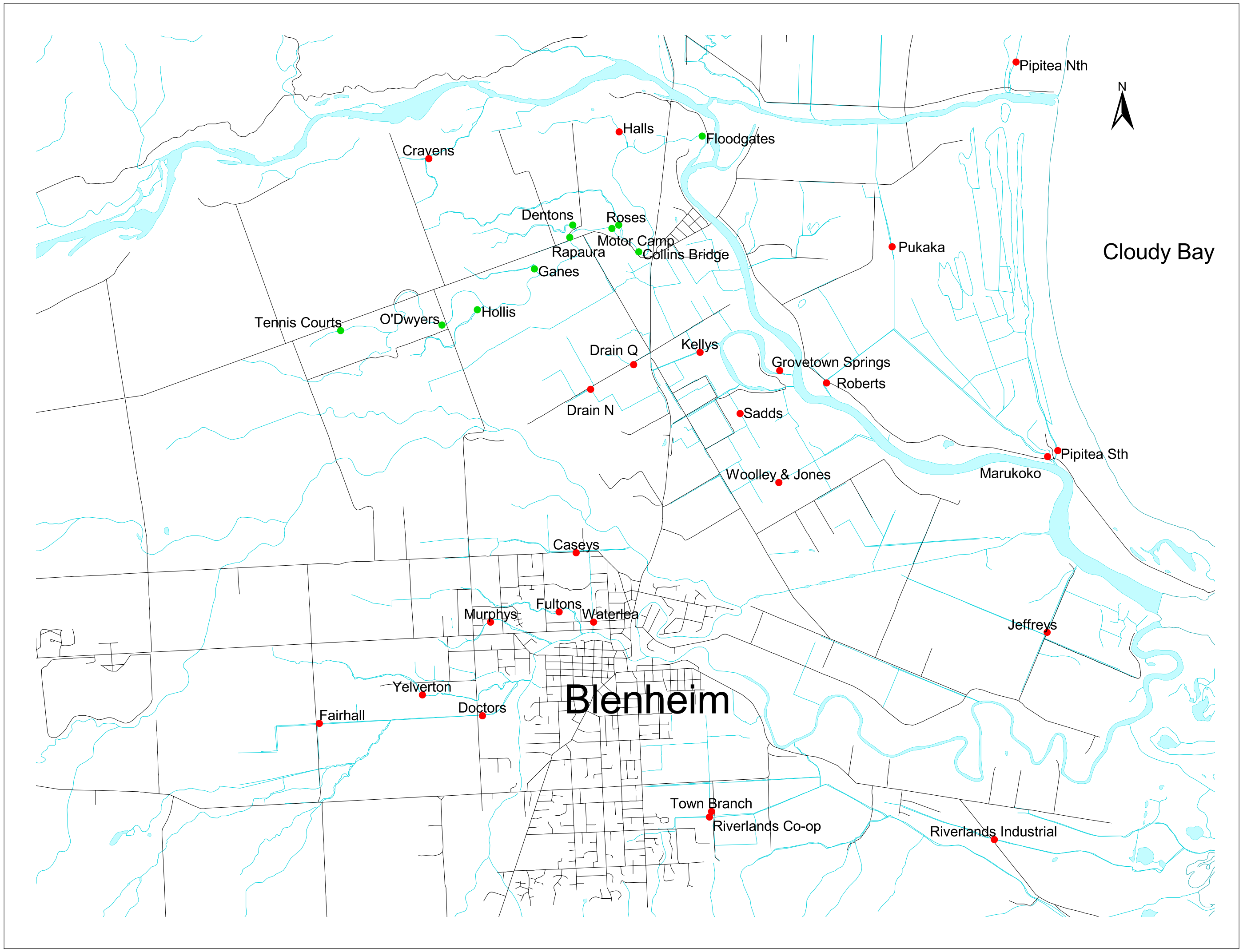


Figure 2 Location of study sites on the Wairau Plain.

2.2 Water quality

At each site water quality samples were collected for analysis of nitrate (NO_3-N), ammonium (NH_4-N), dissolved reactive phosphorus (DRP), total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), inorganic (fixed) suspended solids (FSS), organic (volatile) suspended solids (VSS) and indicator bacteria (*E. coli*). Analyses were undertaken by the Cawthron Institute's IANZ accredited water testing laboratory using appropriate standard methods. Spot measurements of dissolved oxygen, water temperature, turbidity, water clarity, conductivity and pH were measured in the field using standard equipment and techniques. Water quality data used in this report from the 10 additional Spring Creek sites generally were means of 12 monthly samples collected from August 1999 to July 2000 (Young *et al.* 2000). Water temperatures from the additional sites were from spot measurements in February 2000.

2.3 Physical habitat, aquatic plants and riparian condition

At least one representative cross section at each site was surveyed to assess the channel profile, width, depth and the density and diversity of aquatic plants. A tape measure was strung from bank to bank at each cross-section with depth, plant composition, plant density and plant height recorded at 0.2-1.0 m intervals. Species composition and density were determined within a 0.5 m radius of each measurement point. Samples of freshwater algae present were returned to the laboratory for identification.

Cross-section graphs were produced to show the relationship of ground contour and maximum plant height to water surface level. Each cross-section was plotted so that the true left and true right banks correspond with the left and right side of the graph, respectively. Care should be taken interpreting these graphs as they give the impression of continuous plant growth along the cross-section, when in fact there were often height variations and gaps of clean substrate between sample points. Also they give an exaggerated picture of relative plant height because maximum, rather than average, height was used. Nevertheless, the graphs provide a useful baseline for later comparisons and may be particularly useful for weed control monitoring. Cross-section graphs from the additional 10 Spring Creek sites were produced from similar surveys conducted in October 1999 and March 2000 (see Young *et al.* 2000).

Information on shade, riparian land use, surrounding land use, fencing, and stock access at each site was also recorded (Appendix 1).

2.4 Macroinvertebrates

At each site a hand-net was used to sample the range of freshwater insects, crustaceans, worms and snails that were present. These species are known collectively as macroinvertebrates. Macroinvertebrates live almost their entire lives in the water, although many of the insects have aerial adult stages. Some are pollution tolerant whereas others are not. As a result, the presence or absence of some macroinvertebrate species can indicate the ecological health of a stream. Samples were collected by sweeping the hand-net through any aquatic plants present and along the bed and banks of the streams. Samples of this type are not quantitative (*i.e.* you can not get density data from them), but relative abundances of one species versus another at a site can be obtained.

Samples were preserved in 1 litre plastic jars in the field using a mixture of 2 % formalin and 70 % ethanol. In the laboratory, samples were sieved, sorted by eye and identified to the lowest taxonomic level possible using standard keys.

Macroinvertebrate data from the additional 10 Spring Creek sites were obtained from similar hand-net samples collected on 20th October 1999 (Young *et al.* 2000).

Indices used to assist interpretation of macroinvertebrate data included:-

Species richness (or more strictly, taxa richness). This is simply the number of different kinds of animals (= taxa) present. Sometimes the different taxa are resolved down to the species level (*e.g., Austroclima sepia*), but may be at the genera level (*e.g., Austroclima* sp.), or even higher taxonomic level (*e.g.,* Leptophlebiidae), depending upon the practicality of identification.

EPT *taxa.* This is the total number of kinds of mayflies (**E**phemeroptera), stoneflies (**P**lecoptera), and caddisflies (**T**richoptera) found in a sample. These kinds of freshwater insects generally are intolerant of pollution.

Macroinvertebrate Community Index (MCI) values were calculated according to the method of Stark (1985, 1993, 1998). The MCI relies on prior allocation of scores (between 1 and 10) to different kinds of freshwater macroinvertebrates based upon their tolerance to pollution. Types of macroinvertebrates that are characteristic of unpolluted conditions and/or coarse stony substrates score more highly than those found predominantly in polluted conditions or amongst fine organic sediments. In theory, MCI values can range between 200 (when all taxa present score 10 points each) and 0 (when no taxa are present), but in practice it is rare to find MCI values greater than 150. Only extremely polluted or sandy/muddy sites score under 50.

SQMCI (Semi-Quantitative MCI) values were also calculated. Unlike the MCI, which only uses presence-absence data, the SQMCI incorporates relative abundances into the index calculation. SQMCI values, therefore, reflect the abundance and types of macroinvertebrates found at a site.

Although the MCI and SQMCI were developed to assess organic pollution in stony-bottomed streams, they have proven useful in other stream types for assessing habitat quality or environmental health.

2.5 Fish

Where possible, a 50-100 m reach was electric fished at each site using a back-pack electric fishing machine. All fish were identified and released where they had been caught. Many species of fish are more active at night and can be easily seen with a spot-light. Therefore a similar, or longer, length of most springs was spot-lighted at night. Fish were hand netted where possible to verify identification. In addition, fine-meshed fyke nets were set at Pipitea Nth and Marukoko where electric fishing was ineffective because of depth or conductivity. Fyke nets were also set at Drain Q to confirm a spot-light observation of a giant kokopu. The presence and relative abundance of fish species observed at each site using these combined techniques were recorded on NZ Freshwater Fisheries database forms and have subsequently been submitted for inclusion in the database.

3. RESULTS

3.1 Water quality

3.1.1 Site groupings

To identify groups of streams with similar characteristics we used a combination of the physical (width, maximum depth) and water quality variables collected. The majority of these variables were log transformed to improve the normality of the data before analysis. A hierarchical clustering technique based on these combined data identified 4 groups of sites (Figure 3). Riverlands Industrial was placed in a group of its own. The sites nearest to the coast (Jeffreys, Marukoko, Pukaka, Pipitea Nth, Pipitea Sth) were grouped together. The third group consisted of Woolley & Jones, Yelverton, Town Branch and Riverlands Co-op, with the remaining sites in a fourth cluster (Figure 3).

Principal Components Analysis (PCA) was used to help identify the characteristics that separate each site group. PCA is a statistical technique used to condense many variables down to a more manageable number of pseudo-variables (or principal components). Variables that are highly correlated with each other are essentially combined into one principal component. The first principal component (PC1) explained 54% of the total variance in the data and was highly correlated with phosphorus and suspended solids concentrations, turbidity, *E. coli*, and ammonium nitrogen. It was also weakly related with dissolved oxygen and conductivity. The second principal component (PC2) explained 13% of the variance in the data and was highly correlated with nitrate nitrogen and more weakly with water temperature. A plot of the principal component scores for each site is shown in Figure 4. Sites with similar characteristics are plotted closely together, while those with markedly different characteristics are plotted far apart. For further discussion of the characteristics of each site and group see Sections 3.2 and 3.3 below.

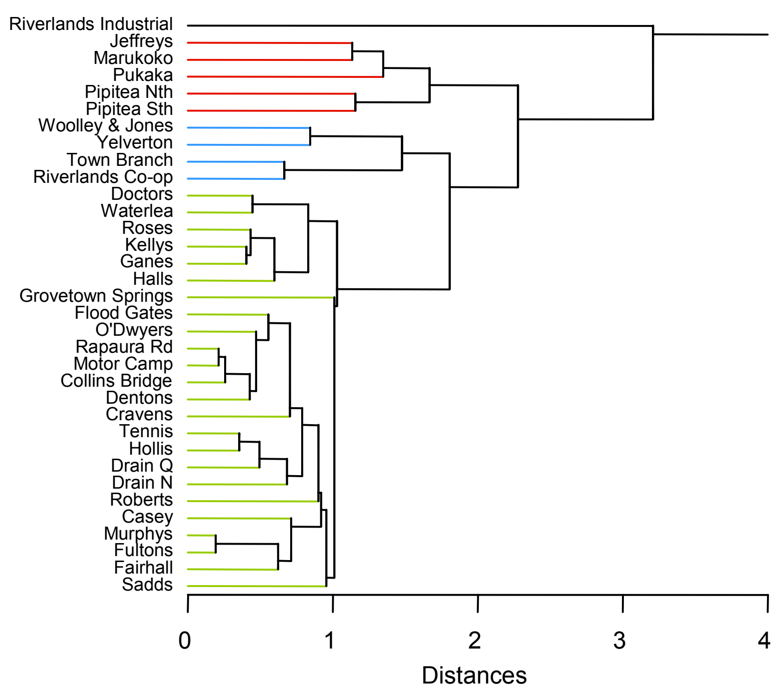


Figure 3 Clustering of the sites based upon physical and water quality variables.

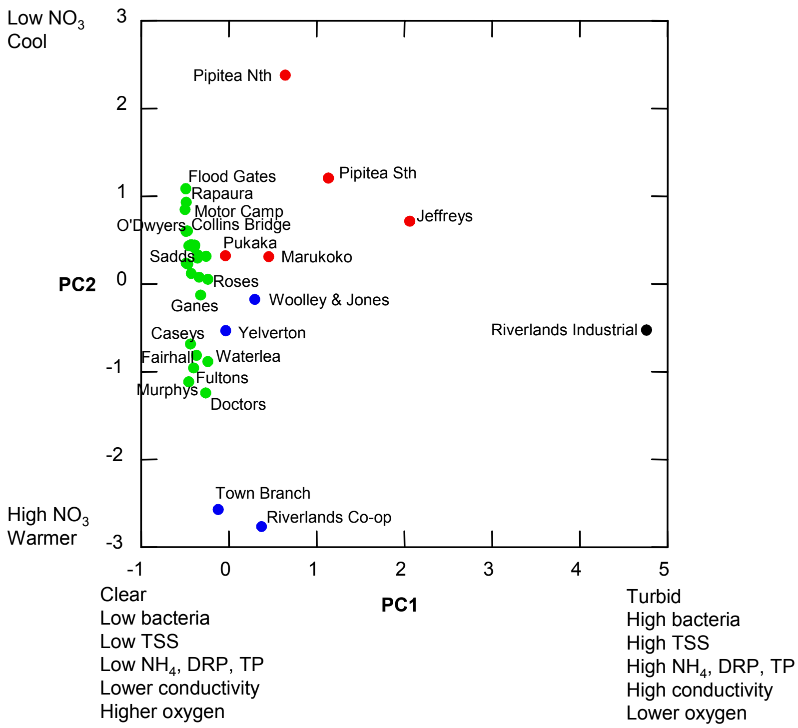


Figure 4 Ordination of sites based upon physical and water quality variables. The colours refer to site groupings identified in Figure 3 above.

3.1.2 Water temperature and connection with the Wairau Aquifer

Temperature measurements of water within, or directly from, the Wairau Aquifer are consistently around 14.0 °C. Therefore our spot measurement of water temperature at each spring-fed stream gave some indication of the likely degree of connection with the aquifer. When water temperature was considerably higher or lower than 14 °C then the connection with the aquifer was *definitely* weak or distant (*i.e.* the temperature of any groundwater that had been on the surface for some time more closely resembled ambient air temperatures). Since we have only single spot measurements for most sites, a reading close to 14 °C does not confirm a close association with aquifer water, however it does indicate that groundwater recently derived from the aquifer *may* provide a considerable portion of the flow.

In general, the 'green' sites appeared to be closely associated with aquifer water, with a few exceptions such as Doctors, Sadds, Fultons, Waterlea, Caseys, Kellys, Murphys, Halls and Ganes (Figure 5). Water temperature at the 'blue' sites indicated a weak or distant connection with the aquifer (Figure 5). Similarly, Riverlands Industrial and the 'red' sites, apart from Pipitea Sth, definitely had weak or distant connections with the aquifer (Figure 5). Pipitea Sth was probably also weakly connected with the aquifer.

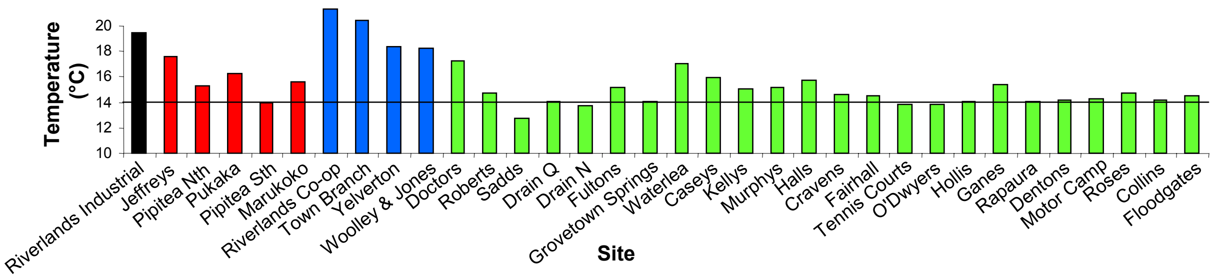


Figure 5 Spot water temperatures measured at each site. The temperature of fresh aquifer water (14 °C) is shown with the horizontal line.

3.1.3 Water quality results

Conductivity at the coastal (red) sites tended to be higher than at the remaining sites (Figure 6). This was particularly the case for Jeffreys, Pipitea Sth and Marukoko, which presumably are influenced by seawater intrusion. Relatively high conductivity at Riverlands Industrial, Riverlands Co-op, Town Branch, Roberts, and Fairhall were likely to be related to inputs of nutrients and other pollutants rather than an influence of seawater (Figure 6).

Dissolved oxygen concentrations were very low at Riverlands Industrial and at all the red sites except Marukoko (Figure 6). Abundant aquatic plant and algae growth, combined with effective tidal flushing, are likely explanations for the very high dissolved oxygen concentrations at Marukoko. Dissolved oxygen concentrations at Yelverton and Woolley & Jones were also relatively low (Figure 6).

Indicator bacteria (*E. coli*) concentrations were extremely high at Riverlands Industrial (20 000 cfu/100ml), and also well above MfE guidelines for swimming and other recreational contact at Riverlands Co-op, Town Branch, Grovetown Springs, Waterlea, Kellys, Halls, Ganes and Roses (Figure 6).

Ammonium nitrogen (NH_4-N) concentrations were relatively high at Riverlands Industrial, Pipitea Sth, Pipitea Nth and at Woolley & Jones (Figure 6). In contrast, nitrate nitrogen (NO_3-N) concentrations were highest at Riverlands Co-op, Town Branch, Doctors, Fultons, Waterlea, Caseys, Murphys, and Fairhall (Figure 6). The high ammonium concentrations and low nitrate concentrations at Riverlands Industrial, Pipitea Nth and Pipitea Sth is probably due to the extremely low dissolved oxygen concentrations which would restrict nitrification - the conversion of NH_4-N to NO_3-N.

Dissolved reactive phosphorus (DRP) concentrations were considerably higher at Riverlands Industrial and the 'red' sites than elsewhere (Figure 6). This phosphorus is likely to come from pollutants at Riverlands Industrial and seawater intrusion at the 'red' sites.

Turbidity was highest at Riverlands Industrial although relatively high turbidities were also observed at the coastal (red) sites and at Riverlands Co-op, Town Branch, Doctors, Sadds, Waterlea and Roses (Figure 6). Drain N, Grovetown Springs, Yelverton, Caseys and Cravens had the lowest turbidity measurements. Very similar patterns were seen with concentrations of suspended solids.

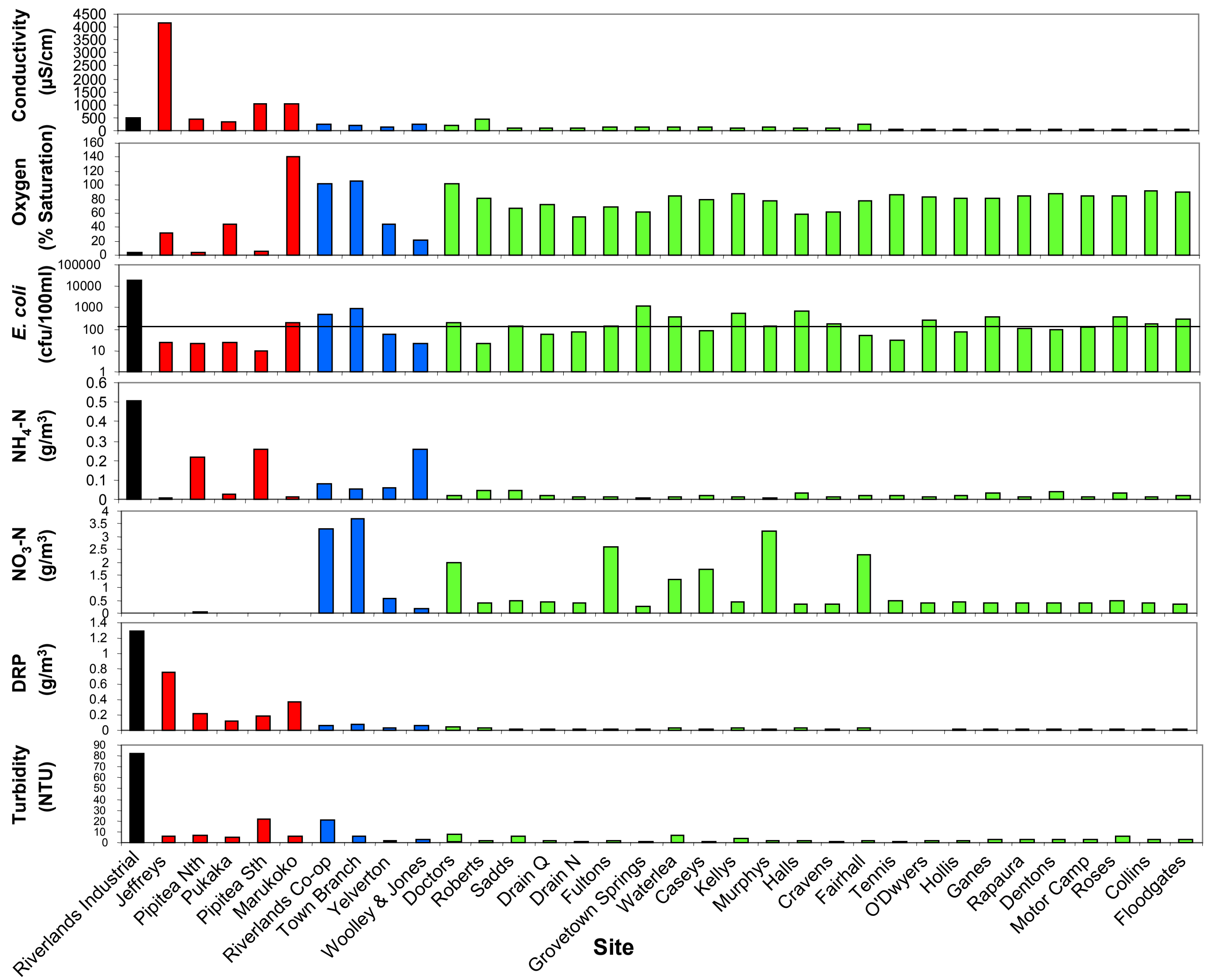


Figure 6 Summary of selected water quality parameters at each of the sites. Note the log scale for *E. coli* and associated contact guideline (126 cfu/100ml).

3.1.4 Water quality summary

In summary, the water quality and physical data indicate that there are four groups of spring-fed streams on the Wairau Plain. The general characteristics of these groups are summarised in Table 1.

Table 1 General description of each site group based on water quality information.

Group	Sites	General characteristics
'Black' sites	Riverlands Industrial	Weak connection with the aquifer, low dissolved oxygen, very high concentrations of bacteria, suspended sediment and nutrients
'Red' sites	Jeffreys, Pipitea Nth, Pukaka, Pipitea Sth, Marukoko	Weak connection with the aquifer, high conductivity indicating seawater influence, variable dissolved oxygen, low bacterial and nitrogen concentrations, high phosphorus concentrations
'Blue' sites	Riverlands Co-op, Town Branch, Yelverton, Woolley & Jones	Weak connection with the aquifer, low conductivity, high nitrogen concentrations
'Green' sites	Doctors, Roberts, Sadds, Drain Q, Drain N, Fultons, Grovetown Springs, Waterlea, Caseys, Kellys, Murphys, Halls, Cravens, Fairhall, Tennis Courts, O'Dwyers, Hollis, Ganes, Rapaura, Dentons, Motor Camp, Roses, Collins, Floodgates	Strong connection with the aquifer, low conductivity, moderate dissolved oxygen concentrations, variable bacterial contamination, low ammonium and phosphorus concentrations, variable nitrate-nitrogen concentrations (high in Taylor/Opawa tributaries, low elsewhere)

3.2 Macroinvertebrates

Seventy-three kinds of macroinvertebrates were identified from 32 spring-fed streams throughout the Wairau Plains (Appendix 2). Pipitea South and Jeffreys were not sampled for macroinvertebrates because of their estuarine nature. The most diverse orders were caddisflies (20 kinds) and true flies (15 kinds), but beetles (9 kinds), molluscs (4 snails and 1 bivalve) and crustaceans (amphipods, shrimp, seed shrimp and koura) were also diverse groups. Mayflies and stoneflies, which are often common in rain-fed, shallow stony streams, were rarely found in these waterways.

Macroinvertebrate indices commonly used to assess stream 'health' are presented in Figure 8, and the dominant macroinvertebrate taxa collected from each site are shown in Table 2. Communities showed considerable variation in quality within each of the groups of streams that were determined using physical and water quality variables (Section 3.1.1), particularly within the large 'green' group where sites ranged from those with diverse assemblages dominated by relatively sensitive amphipods (*e.g.,* Spring Creek sites such as Cravens, O'Dwyers and Motor Camp), to those with low taxa richness and dominance by tolerant annelid worms (*e.g.,* Sadds, Murphys). However, some broad differences could be seen between the four groups, with the "black" (Riverlands Industrial), "red" (Pipitea North, Pukaka, Marukoko) and "blue" (Riverlands Co-op, Town Branch, Yelverton, Woolley & Jones) sites generally having poorer quality macroinvertebrate communities than the good quality sites in the "green" group.

All of the biotic indices suggested that the community at Riverlands Industrial was highly degraded (Figure 8). The macroinvertebrate community was dominated by worms and the snail *Physa* (Table 2). These are both very tolerant taxa, capable of flourishing in the degraded waters at this site (see

Section 3.3). Seed-shrimp (Ostracoda) were the only kind of crustacean present (Table 2), and taxa diversity was low. The sole EPT taxon at the site was a relatively tolerant caddisfly species, *Triplectides cephalotes*. Consequently, the MCI and SQMCI scores were both low.

Figure 7 A large koura from Cravens Creek.

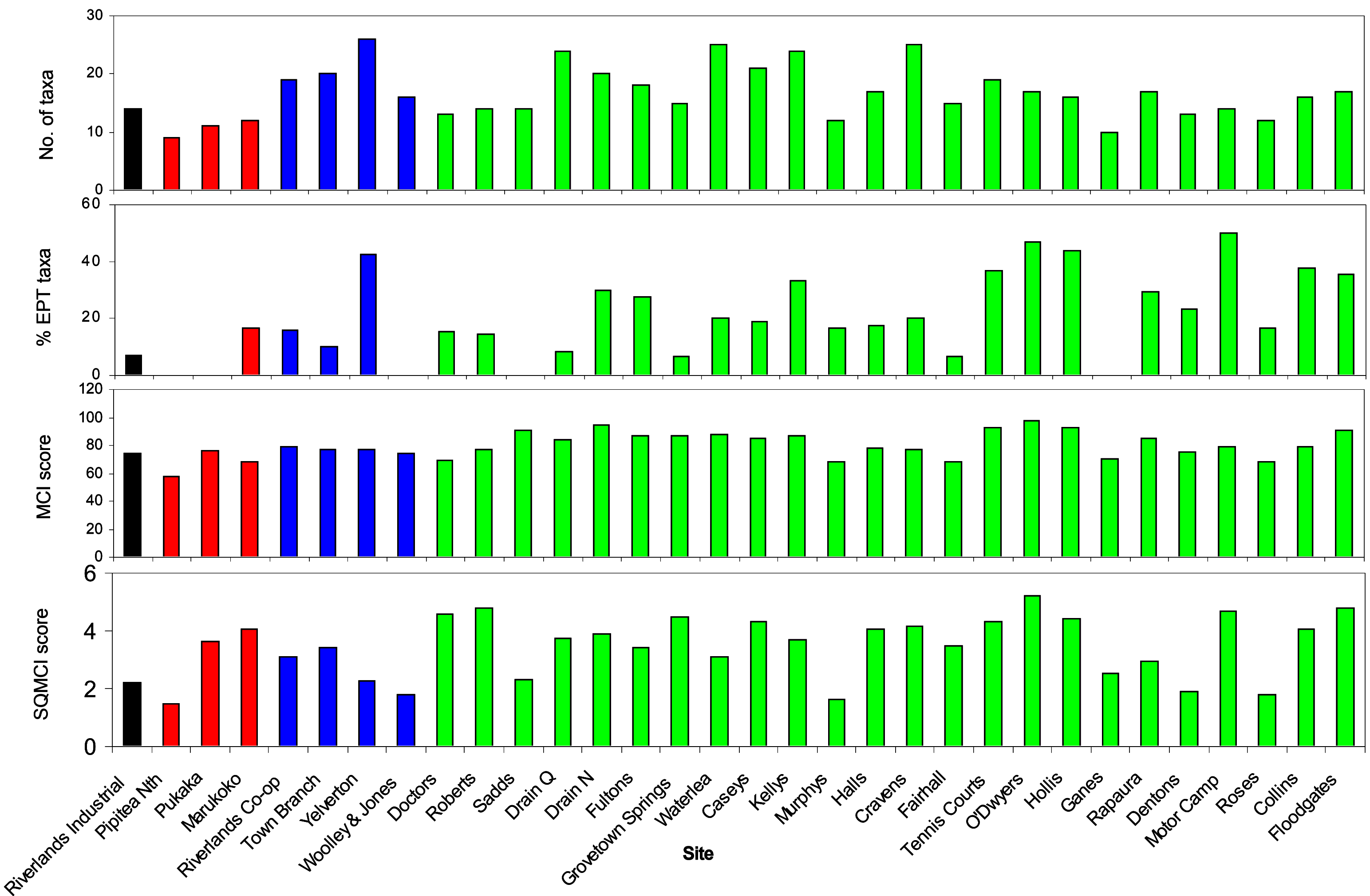


Figure 8 Summary of biotic indices at each of the sites. Colours relate to site groupings identified in Section 3.1.

Table 2 Dominant macroinvertebrate taxa throughout the Wairau Plain Springs. Site colours relate to groupings from Section 3.1.1

Dominant Taxon	**Taxon score**	Riverlands Industrial	Pipitea Nth	Pukaka	Marukoko	Riverlands Co-op	Town Branch	Yelverton	Woolley & Jones	Doctors	Roberts	Sadds	Drain Q	Drain N	Fultons	Grovetown Springs	Waterlea	Caseys	Kellys	Murphys	Halls	Cravens	Fairhall	Tennis Courts	O'Dwyers	Hollis	Ganes	Rapaura	Dentons	Motor Camp	Roses	Collins	Floodgates
Caddisflies																																	
Oxyethira	2					■																											
True Flies																																	
Chironomus	1		■						■																								
Orthocladiinae	2																												■				
Crustacea																																	
Amphipoda	5			■						■	■				■	■		■				■	■	■	■	■		■		■		■	■
Ostracoda	3			■													■						■										
Worms	1	■						■	■			■			■		■			■							■	■	■		■		
Snails																																	
Physa	3	■		■		■																											
Potamopyrgus	4			■	■	■	■						■	■	■	■		■	■		■	■		■			■						

Macroinvertebrate communities at the 'red' sites varied in quality, but all three sites that were sampled had low taxa and EPT diversity. The low MCI and SQMCI scores and dominance by highly tolerant bloodworms (*Chironomus zealandicus*) at Pipitea North indicate that this site is of poorer quality than the other red sites. In addition, no crustacean taxa were found there (Table 3). This probably is a function of the wetland habitat (compared with the channelised morphology of Pukaka and Marukoko), where the lack of flow and low oxygen concentration only allow the most tolerant species to survive. In contrast, SQMCI scores were relatively high at Pukaka and Marukoko. At Pukaka, this was due to dominance by a range of relatively sensitive taxa (amphipods, seed-shrimp/Ostracoda and snails *Physa* and *Potamopyrgus*), whereas at Marukoko only *Potamopyrgus* was dominant, but amphipods also occurred in abundance. The estuarine and anoxic Jeffreys and Pipitea South sites were not sampled for invertebrates but probably supported few freshwater taxa, with only some of the highly tolerant worm, bloodworm or snail taxa likely to inhabit such waters.

There was considerable variation amongst the four 'blue' sites, despite their similarity in water quality/physical variables. Although all four sites had similar MCI scores (which approximated the median value for all of the sites), they were dominated by different taxa, and taxa richness, % EPT taxa and SQMCI varied between the sites. However, Riverlands Co-op and Town Branch were reasonably similar and were both dominated by snails (*Potamopyrgus* and *Physa* at Riverlands Co-op; *Potamopyrgus* at Town Branch), with *Oxyethira* (a tolerant cased-caddis larvae) also dominant at Riverlands Co-op. Both sites had relatively high taxa richness (higher than that at any of the black or red sites, and many of the green sites), but % EPT taxa was low. SQMCI scores were also low, but were higher than those at Yelverton and Woolley & Jones. In contrast, Yelverton had very high taxa richness (26 taxa) and % EPT taxa (42 %) due to the high diversity of caddisflies. This was almost certainly due to the low water level, which had created shallow 'riffles' over the coarse gravel substrate – a habitat that is not normally found in lowland spring-fed systems, but that favors colonisation by caddisflies. Despite this diversity, worms were the dominant taxon and the low SQMCI score was indicative of a poor quality community. Woolley & Jones had the poorest quality macroinvertebrate fauna of the four blue sites. Taxa diversity was relatively low, no EPT taxa were present and the SQMCI score was very low. Worms and bloodworms were the dominant taxa. Shrimp and koura were not observed at any of the 'blue' sites, but amphipods and seed-shrimps were present at all four sites (Table 3).

The quality of macroinvertebrate communities at sites in the 'green' group varied enormously, with taxa richness ranging from 10 (Ganes) to 25 (Cravens & Waterlea), % EPT from 0 (Sadds & Ganes) to 50 (Motor Camp), MCI from 68 (Murphys & Roses) to 98 (O'Dwyers) and SQMCI from 1.64 (Murphys) to 5.20 (O'Dwyers).

The SQMCI index indicated that communities were of poorest quality at Sadds, Fultons, Waterlea, Murphys, Fairhall, Ganes, Rapaura, Dentons and Roses (SQMCI < 3.50). All but one of these sites were dominated or co-dominated by worms (with the exception of Fairhall which was dominated by Crustacea), and almost half of the sites (Sadds, Fultons, Waterlea and Murphys) were denuded of aquatic plants that provide habitat for more sensitive fauna such as amphipods. The highest quality communities occurred at Doctors, Roberts, Grovetown Springs, Caseys, Halls, Cravens, Tennis Courts, O'Dwyers, Hollis, Motor Camp, Collins and Floodgates (SQMCI > 4.00). These sites all supported lush aquatic plant growth, and tended to be dominated by amphipods and/or the snail *Potamopyrgus*. Drain Q, Drain N and Kellys had more intermediate SQMCI scores, ranging from 3.66 – 3.90. Quality of macroinvertebrate communities in these streams is likely to vary temporally and spatially in response to changes in habitat, such as clearance of aquatic plants from in and around the channel. Sampling carried out previously (on three occasions) in Murphys Stream at a different site where aquatic plants had established (downstream near the confluence with the Taylor River), found snail or amphipod-dominated communities (*c.f.* the worm-dominated community in this study) with considerably higher % EPT taxa, MCI and SQMCI scores than were found in this study (Crowe 2002).

MCI scores showed a similar pattern to the SQMCI, but generally showed less variation between sites. In some cases the MCI score was indicative of considerably better quality than the SQMCI score (*e.g*., Sadds), due to the presence of low numbers of more sensitive taxa (several beetles, waterbugs and damselflies at Sadds). The SQMCI score down-weights rare taxa and places more importance on more abundant/dominant taxa (worms at Sadds), and therefore probably gives a more realistic assessment of the health of a site.

Most sites with high taxa richness and a high proportion of EPT taxa were those with SQMCI scores at the higher end of the range, such as Caseys, Kellys, Cravens, Drain N and Drain Q (high taxa richness), and Tennis Courts, O'Dwyers, Hollis and Motor Camp (high % EPT). However, taxa richness and % EPT taxa did not seem to be strongly linked with SQMCI results, with many of the sites with higher SQMCI scores having relatively low diversity of taxa and % EPT taxa. Furthermore, Waterlea (which had a low SQMCI score) had a very high taxa richness, and Rapaura and Dentons (also with low SQMCI scores) had relatively high proportions of EPT taxa due to presence of mayfly and caddis taxa. Regression analysis indicated that there was a significant relationship between percentage cover by aquatic plants and the proportion of EPT taxa ($F_{1,30}=10.32$, $P<0.005$), with the proportion of EPT taxa increasing as aquatic plant cover increased. In contrast, there was no evidence that streams with a high proportion of aquatic plant cover had higher taxa richness.

Crustacean taxa were found at all of the 'green' sites except Sadds, but Ganes also had a poor crustacean fauna with only low numbers of seed-shrimp present (Table 3). Amphipods were fairly ubiquitous, occurring at all of the sites except Sadds and Ganes, whereas shrimp occurred only at Roberts, Grovetown Springs, Waterlea, Halls, Cravens and Floodgates. Koura were found at 18 of the 24 'green' sites, and in many cases were observed by spotlight or electric-fishing, rather than in hand net samples. Koura were not observed at Doctors, Roberts, Sadds, Grovetown Springs, Murphys and Ganes. Koura have a wide, but patchy, spatial distribution across the Wairau Plain (Figure 9). Waterlea, Halls, Cravens and Floodgates were the only sites at which amphipods, shrimp and koura were all observed. It is interesting that Waterlea supported a diverse crustacean fauna despite the lack of aquatic plant growth in the channel, and it is likely that these taxa would become more dominant if plant biomass (*i.e.,* habitat) increased.

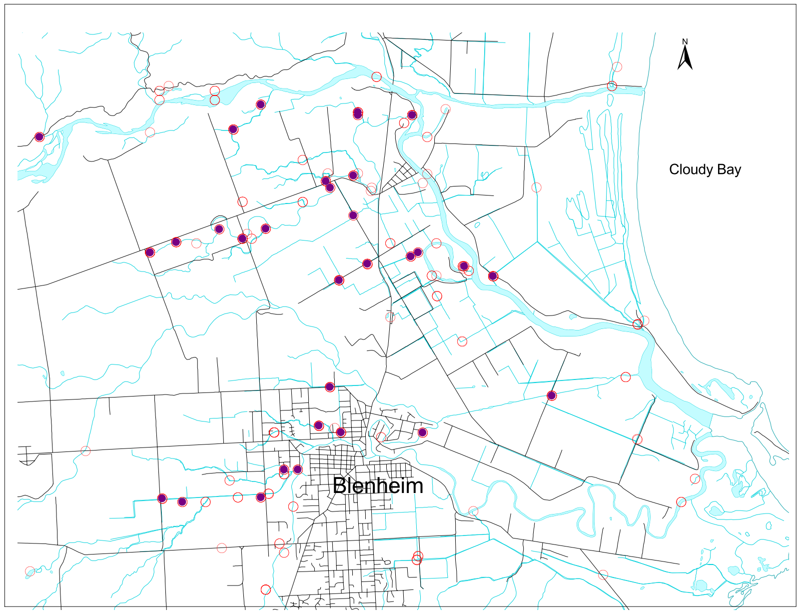


Figure 9 Distribution of koura (*Paranephrops planifrons*) across the Wairau Plains. Open circles are sampling sites, filled circles indicate koura presence.

Table 3 Distribution of Crustacea throughout the Wairau Plain springs. Site colours relate to groupings from Section 3.1.1.

Taxon	Riverlands Industrial	Pipitea Nth	Pukaka	Marukoko	Riverlands Co-op	Town Branch	Yelverton	Woolley & Jones	Doctors	Roberts	Sadds	Drain Q	Drain N	Fultons	Grovetown Springs	Waterlea	Caseys	Kellys	Murphys	Halls	Cravens	Fairhall	Tennis Courts	O'Dwyers	Hollis	Ganes	Rapaura	Dentons	Motor Camp	Roses	Collins	Floodgates
Seed-shrimp	■		■		■	■	■	■	■			■		■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Amphipods			■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■
Shrimp										■					■	■				■	■											■
Koura												■	■	■		■	■	■		■	■	■	■	■	■		■	■	■	■	■	■

A DECORANA ordination of macroinvertebrate communities using presence-absence data is presented in Figure 10. The separation of sites is proportional to the relative similarity of their macroinvertebrate communities. Sites were colour-coded according to the site groupings identified in Section 3.1.1. Characteristic taxa (from a taxon ordination which is not shown) are plotted near the sites where they were most commonly represented.

Site distribution was remarkably similar to that in the ordination of physical and water quality variables (compare Figure 10 with Figure 4). The 'green' sites were, for the most part, located in a similar location on the left side of the ordination, and were most highly correlated with the occurrence of Crustacea such as amphipods and koura (*Paranephrops*), as well as the more sensitive mayfly (*Austroclima*, *Zephlebia*) and caddisfly (*Pycnocentria*, *Psilochorema*, *Polyplectopus*) taxa. Some lower scoring (less sensitive) taxa were also correlated with these sites, such as blackfly larvae (*Austrosimulium*), freshwater bivalves (Sphaeriidae) and midge larvae (*Tanytarsus*). Sites in the Spring Creek system that were sampled in October 1999 were located in a similar region of the ordination, and were very close to the other 'green' sites considering that they were collected several years earlier, and at a different time of year. Sadds was separated from the other 'green' sites, and was strongly correlated with the presence of "pond-dwelling taxa" such as beetles (Stratiomyidae, *Enochrus*, *Liodessus*), springtails (Collembola), pond-skaters (*Microvelia*), and to a lesser extent, larvae of damselfly *Austrolestes*.

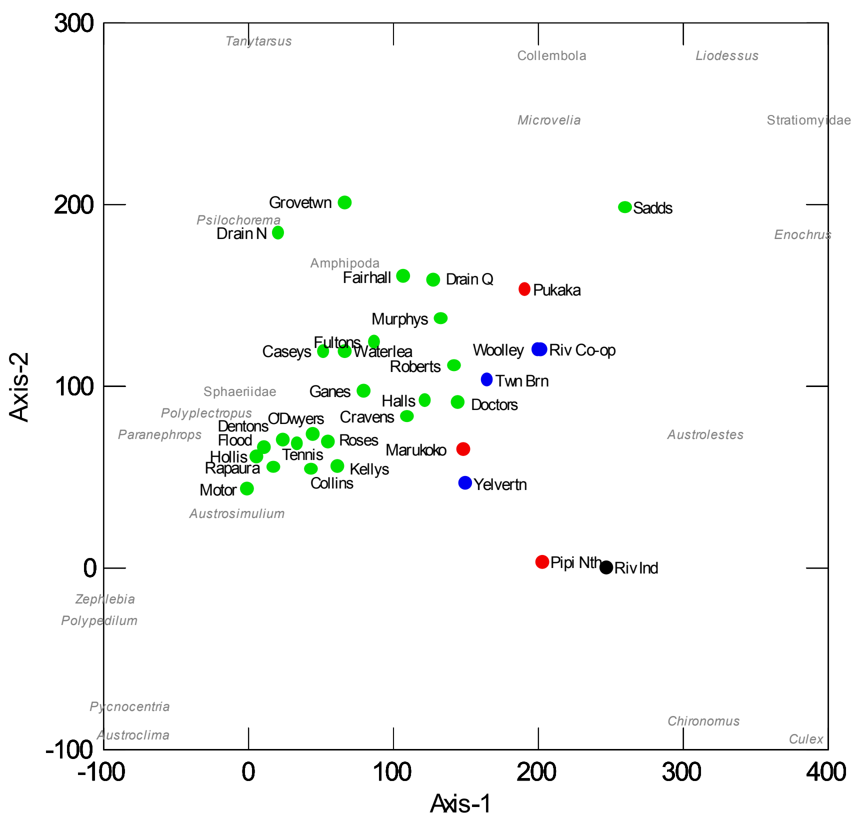


Figure 10 DECORANA ordination of macroinvertebrate communities using presence-absence data. Sites with the most similar macroinvertebrate communities are plotted closest together. Colours relate to site groupings identified in Section 3.1.1.

The 'blue' and 'red' sites had similar site distributions in the central-right region of the ordination, and were more closely correlated with the 'pond-dwelling taxa' (particularly damselfly larvae) than the 'green' sites. Pipitea North was positioned close to Riverlands Industrial on the right side of the ordination, and both sites were correlated with the presence of bloodworms (*Chironomus*) and mosquito larvae (*Culex*).

Analysis for correlation of site distributions with environmental variables (physical and water quality data) indicated that site distribution along Axis-1 was positively correlated with ammonia-N, temperature, total, fixed and volatile suspended solids, specific conductivity, dissolved reactive phosphorus, total phosphorus and turbidity. Channel width and volatile suspended solids were negatively correlated with site distribution along Axis-2, but there did not appear to be strong site separation along this axis.

In summary, the macroinvertebrate data supported our initial site groupings based on the water quality and physical information. The only real exception to this was the invertebrate community at Sadds, which appears to be different and of poorer quality than that at the other 'green' sites and more similar to that at the 'blue' and 'red' sites.

3.3 Aquatic plants

Forty-three different kinds of plants were recorded in or surrounding the sites surveyed (Table 4). Of these 18 were primarily aquatic, whereas the remaining 25 were associated with the margins of waterways or were purely terrestrial plants. Twelve of the aquatic plants were introduced species. The most common species recorded were duckweed, mixed pasture grasses, watercress, and swamp willow weed. Nuisance species such as *Egeria* and *Lagarosiphon* were found at Roberts, Kellys, Halls, Marukoko, Riverlands Co-op, Fultons, Waterlea, Caseys, and Murphys. *Glyceria maxima* was found only at Grovetown Springs.

The total number of plant species recorded from the Wairau Plain springs exceeded those found during the Spring Creek study – 20 (Young *et al.* 2000), because a greater number of wetland margin and terrestrial plant species were recorded in this survey.

Most of the streams surveyed are subject to regular aquatic plant control. Control methods vary and include herbicide, mechanical control, hand clearing and combinations of these. Herbicide is also applied to bankside vegetation in some waterways. Recent control work was evident in some of these streams, making an assessment of typical plant assemblage difficult at some sites. Because of the regular control work, species presence and composition will vary markedly over time. Our description of plants is only a "snap shot" and could change dramatically depending on control work.

The positive values of aquatic plants in waterways sometimes are overlooked, particularly when the focus of attention is on the rampant growth of nuisance plants. Under these circumstances, and understandably, any plants growing in the water are perceived as a nuisance. This perception has caused aquatic plants to be most often referred to as weeds and even for many plants to be named as such, *e.g*., Willow weed, Duckweed, Pondweeds *etc*. Because we recognise that these plants can be a useful component of aquatic ecosystems, we have preferred to describe them as "aquatic plants".

Aquatic plants provide ecological and biological benefits which may include:

- Trapping and stabilisation of sediments
- Uptake and release of nutrients
- Added surface area for algal production, aquatic insects and molluscs
- Shelter and feeding areas for fish
- Provide and host food sources for waterfowl

Some aquatic plants, such as watercress and raupo, are a food source, while these and others have cultural values. For some people, aquatic plants have a pleasing aesthetic value, adding character, texture and visual diversity to the aquatic scene.

It is not possible or necessary to manage aquatic plant growth in the same way for all watercourses. The need for aquatic plant removal can be justified where plant growth affects water levels and properties are at risk or land use is affected because of ineffective drainage. Because of the variety of spring fed watercourses within the Wairau spring belt, there is scope for a variety of approaches to the management of aquatic plants within them. For those watercourses that do not have nuisance plant species and pose less risk of flooding, aquatic plant growth is not an issue. Other watercourses that do have nuisance plant species, but high biological values, require innovative management so that control does not impact on these values.

One of the best techniques that can be used to selectively weed out nuisance aquatic plants and leave behind the more benevolent species is hand clearing. However, wherever examples of hand clearing were found in the Wairau springs, the watercourse had generally been transformed into a relatively sterile habitat with complete plant removal. Selective removal of nuisance aquatic plants may provide a better balance between the drainage and ecosystem values of these springs. Control of plants, particularly along narrow watercourses, can also be achieved by encouraging growth of riparian vegetation, which will shade and suppress aquatic plant growth (Young *et al.* 2000). Even grasses and sedges can fill this role along very narrow watercourses.

Table 4 Distribution and percent cover of aquatic plant species in the Wairau Plain springs. Site colours relate to groupings from Section 3.1.1.

Common name	Scientific name	Riverlands Ind	Jeffreys	Pipitea Nth	Pukaka XS1	Pukaka XS2	Pipitea Sth	Marukoko	Riverlands Co-op	Town Branch	Woolley & Jones	Yelverton	Doctors	Roberts XS1	Roberts XS2	Sadds XS1	Sadds XS2	Sadds XS3	DrainQ XS1	DrainQ XS2	DrainQ XS3	DrainN XS1	DrainN XS2	DrainN XS3	Fultons	Grovetown Sp	Waterlea	Caseys	Kellys	Murphys	Halls	Cravens	Fairhall
Alder *	*Alnus glutinosa*																														x		
Cape pondweed *	*Aponogeton distachyus*																													x			
Azolla	*Azolla filiculoides*	4			8	36							1.5				4	5	2														
Beggar's ticks *	*Bidens frondosa*										x																		x				
Starwort *	*Callitriche stagnalis*								0.5	x		4	29															5					x
Unnamed sedges	*Carex* spp.	6	x	0.8	x			4	x	x						6		4								x	4		5	x	x		
Bachelor's button	*Cotula coronopifolia*		29																												3		
Hawthorn *	*Crataegus* spp.										x																						
Egeria *	*Egeria densa*													49															2		15		
Canadian pondweed *	*Elodea canadensis*																								x				3				
Floating sweetgrass *	*Glyceria fluitans*											8											10		x		1					8	14
Reed sweetgrass *	*Glyceria maxima*																									19							
Oxygen weed *	*Lagarosiphon major*							2	24					25											x		1	23	5	x	x		
Duckweed	*Lemna minor*	69		1.3	82	38	64			x	80		4	3		75	70	77	78	3	7	28	37	25		1.5	2	15	0.5		17	14	8
Lilaeopsis	*Lilaeopsis novae-zelandiae*												0.5																				
Primrose willow *	*Ludwigia peploides*																									0.5							
Mint	*Mentha* spp.																													x			
Monkey musk*	*Mimulus guttatus*									x		3														8			1				
Water forget-me-not *	*Myosotis laxa*								6	x			1																		0.5		
Nitella	*Nitella hookeri*							43					5									1	39		x				15		7	24	
Water lily *	*Nymphaea alba*																													x			
Phalaris *	*Phalaris spp.*										x																						
NZ Flax	*Phormium tenax*			10																										x			
Pittosporum	*Pittosporum* spp.																																x
Broad-leaved plantain*	*Plantago major*				x																												
Willow weed *	*Polygonum persicaria*																												53				
Swamp willow weed	*Polygonum salicifolium*								2	x		15	8				7			81		30		25		46		36	13	x	29	0.5	7

Table 4 cont.

Common name	Scientific name	Riverlands Ind	Jeffreys	Pipitea Nth	Pukaka XS1	Pukaka XS2	Pipitea Sth	Marukoko	Riverlands Co-op	Town Branch	Woolley & Jones	Yelverton	Doctors	Roberts XS1	Roberts XS2	Sadds XS1	Sadds XS2	Sadds XS3	DrainQ XS1	DrainQ XS2	DrainQ XS3	DrainN XS1	DrainN XS2	DrainN XS3	Fultons	Grovetown Sp	Waterlea	Caseys	Kellys	Murphys	Halls	Cravens	Fairhall
Curly pondweed *	*Potamogeton crispus*							1	50	x			2																		15	23	
Blunt pondweed	*Potamogeton ochreatus*																														0.5		
Water buttercup *	*Ranunculus trichophyllus*							2					47																		3		
Riccia *	*Riccia fluitans*																											4.5		x			
Watercress *	*Rorippa nasturtium-aquaticum*				3.5				7	x		69	2	1						3	74		2	5	x	23		18		x	10	11	49
Marsh yellow cress	*Rorippa palustris*											1																					
Horse's mane weed	*Ruppia polycarpa*		71																														
Crack willow *	*Salix fragilis*			88																									x				
Raupo	*Typha orientalis*				6	26	29	8																									
Gorse *	*Ulex europaeus*				x	x																											
Algae								7																									
Blackberry *				x												x																	
Manuka				x																													
Mixed pasture grasses		19	x		x	x	7	7	10	x	20	x	x	23		19	19	14	20	13	19	41	13	45		2	54		2	x		20	22
Tree Lucerne *																												x					
Unnamed native shrubs																																	x
Unnamed rushes		2	x	0.5	0.5			26	0.5				x													x			2	x	x		
% instream plant cover		100	12	100	91	86	100	57	89	0	100	92	73	92	0	100	94	100	100	100	100	100	74	100	0	100	17	14	82	0	86	54	79
total species		5	2	5	6	3	3	9	8	7	2	6	10	5	0	3	4	4	3	4	3	4	5	4	5	7	5	6	11	9	11	7	6

Shaded common names indicate aquatic plants. * = introduced species x = present but not recorded in the cross-section.

3.4 Fish

Six different species of fish were found during our survey of the Wairau Plain springs. These include the native longfin eel (*Anguilla dieffenbachii*), shortfin eel (*Anguilla australis*), giant kokopu (*Galaxias argenteus*), inanga (*Galaxias maculatus*) and common bully (*Gobiomorphus cotidianus*), as well as the introduced brown trout (*Salmo trutta*). Yelloweye mullet (*Aldrichetta forsteri*), a largely estuarine/marine species, were seen at the confluence of the Pipitea Sth/Marukoko and the Wairau River. In addition to the above species, lamprey (*Geotria australis*) and black flounder (*Rhombosolea retiaria*) have been recorded in the Spring Creek catchment (Young *et al.* 2000). A large bodied galaxiid, thought to be a banded kokopu (*Galaxias fasciatus*) was also observed by spot-light at the Tennis Courts site on Spring Creek (Young *et al.* 2000). Giant bully (*Gobiomorphus gobioides*) and common smelt (*Retropinna retropinna*) have been recorded in the NZ freshwater fisheries database from the Roses Overflow and may also be found in some of the spring-fed streams where access to and from the sea is easy.

Shortfin eels were the most common species of fish found in the springs (Figure 12, Table 5). Inanga (Figure 13) and common bullies (Figure 15) were also widespread, while longfin eels (Figure 11) and brown trout (Figure 14) were only found occasionally. Only two individual giant kokopu were seen -- in Drain N and Drain Q (Figure 16). These are the first officially recorded sightings of giant kokopu in the Wairau Plain area since 1973, although Mr R. Winter reported the capture of a giant kokopu in Spring Creek in 1985 (see Young *et al*. 2000). The only other record of giant kokopu from the Wairau River catchment is a 1988 record from the Onamalutu River. We also saw an unidentified galaxiid in Roberts but it was not possible to confirm whether this was a banded or giant kokopu.

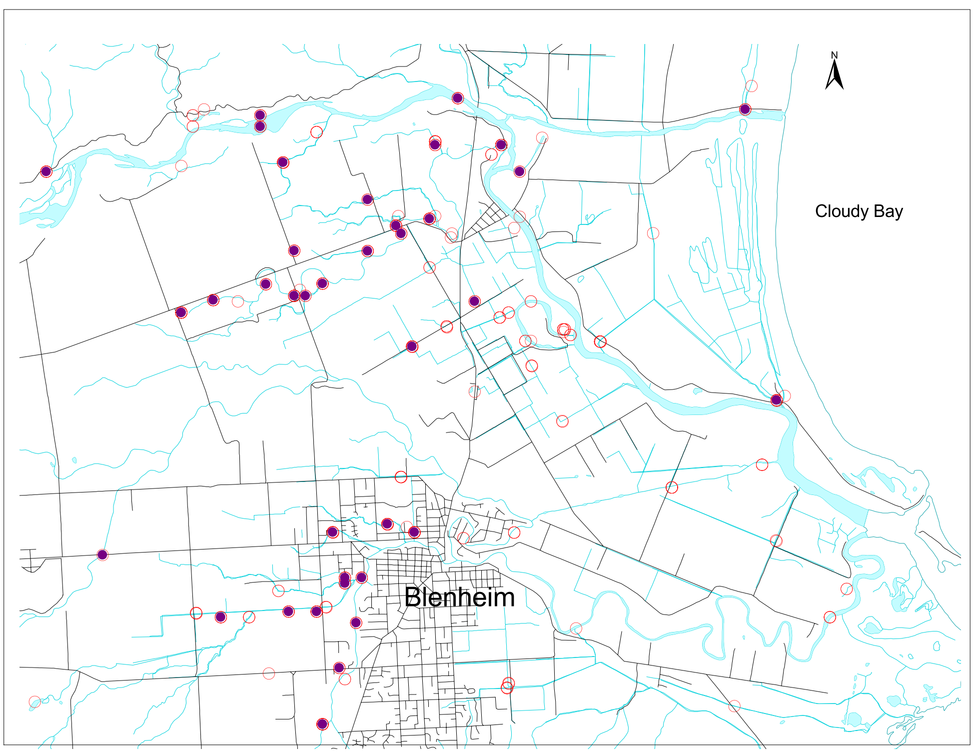


Figure 11 Distribution of longfin eels (*Anguilla dieffenbachii*) across the Wairau Plain. Fish survey sites are shown with open circles, longfin eel presence is shown with filled circles.

Figure 12 Distribution of shortfin eels (*Anguilla australis*) across the Wairau Plain. Fish survey sites are shown with open circles, shortfin eel presence is shown with filled circles.

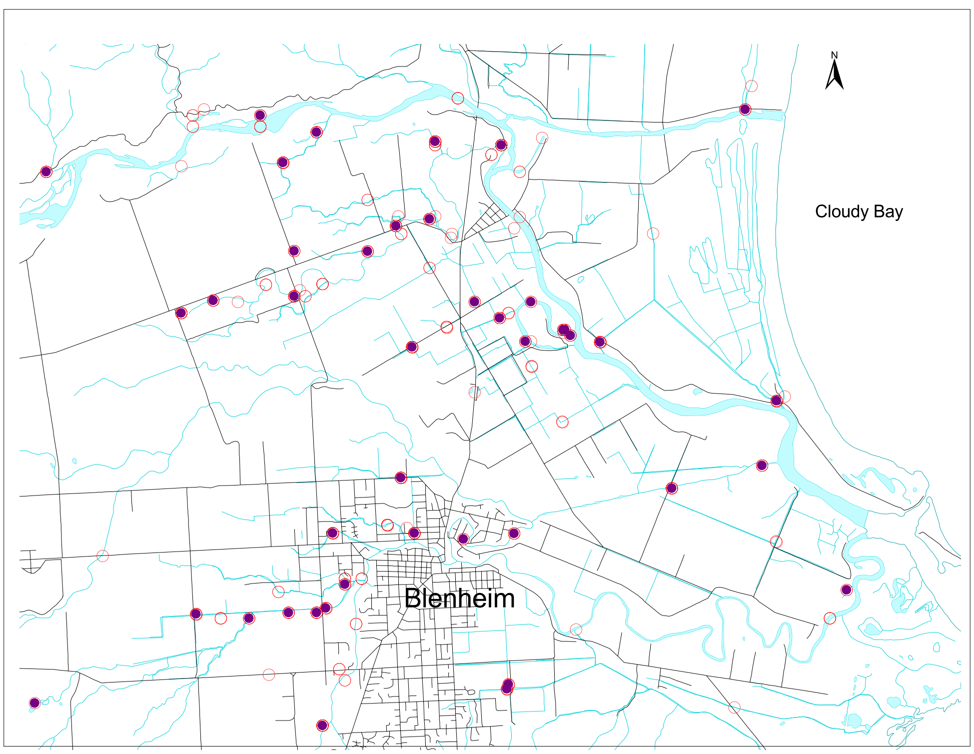


Figure 13 Distribution of inanga (*Galaxias maculatus*) across the Wairau Plain. Fish survey sites are shown with open circles, inanga presence is shown with filled circles.

Figure 14 Distribution of brown trout (*Salmo trutta*) across the Wairau Plain. Fish survey sites are shown with open circles, brown trout presence is shown with filled circles.

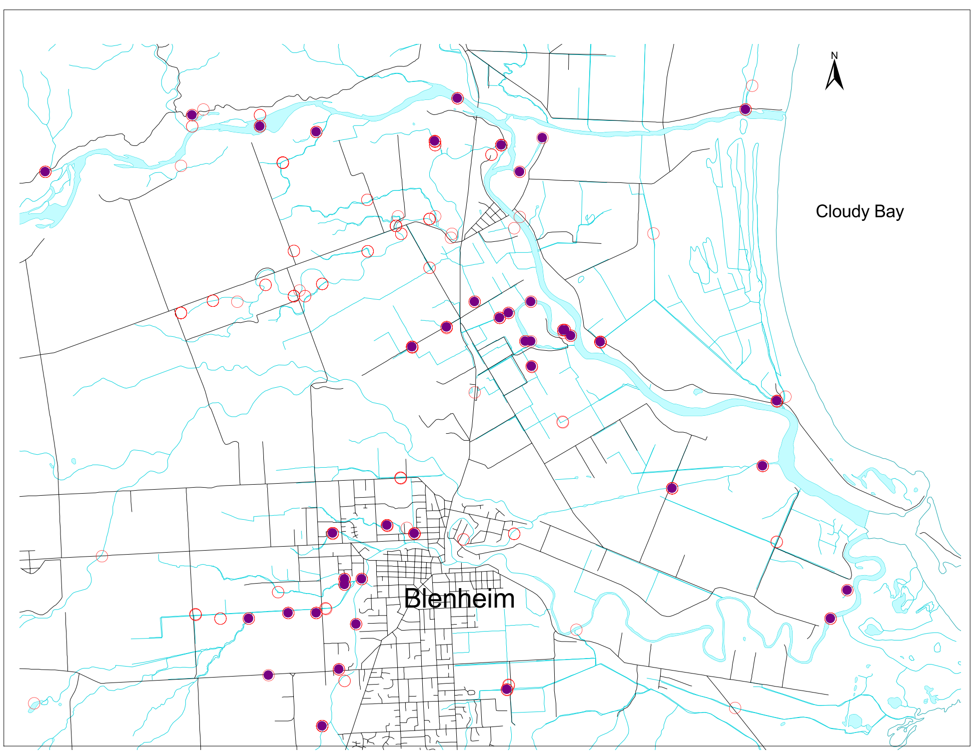


Figure 15 Distribution of common bully (*Gobiomorphus cotidianus*) across the Wairau Plain. Fish survey sites are shown with open circles, common bully presence is shown with filled circles.

Figure 16 Giant kokopu (*Galaxias argenteus*) found at Drain Q

The distribution of fish species was consistent with the site groupings based on water quality and physical variables developed in Section 3.1.1. Fish diversity generally was high at the 'green' sites, although Sadds was perhaps an exception with only two fish species recorded and thus was more closely aligned with a 'red' or 'blue' site. No fish were found in Riverlands Industrial ('black' site) and, apart from Marukoko, fish diversity at the 'red' sites was very poor also (Table 5).

Although water quality and physical conditions at sites determine their suitability for fish, the key aspect governing the presence of fish at any of these sites is access. For example, Pipitea South was sampled just upstream of its lower floodgate and no fish were found there. In contrast, yelloweye mullet and inanga were abundant immediately below the floodgate. If fish passage could be improved through the floodgate more habitat would be made available to these species.

Table 5 Distribution of all fish species throughout the Wairau Plain springs. Unconfirmed sightings are shown with cross-hatching. Site colours relate to groupings from Section 3.1.1.

Species	Riverlands Industrial	Jeffreys	Pipitea Nth	Pukaka	Pipitea Sth	Marukoko	Riverlands Co-op	Town Branch	Woolley & Jones	Yelverton	Doctors	Roberts	Sadds	Drain Q	Drain N	Fultons	Grovetown Springs	Waterlea	Caseys	Kellys	Murphys	Halls	Cravens	Fairhall	Tennis Courts	O'Dwyers	Hollis	Ganes	Rapaura	Dentons	Motor Camp	Roses	Collins	Floodgates
Lamprey																																		■
Longfin eel						■					■				■	■		■			■	■	■	■	■	■	■	■	■	■	■	■	■	■
Shortfin eel		■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Giant kokopu												▦		■	■											■								
Banded kokopu																									▦									
Inanga						■	■	■			■	■			■	■	■	■	■	■	■	■	■	■	■	■		■			■			■
Brown trout												■			■	■			■	■	■	■	■		■	■	■		■	■	■	■	■	■
Common bully						■	■				■	■	■	■	■	■	■	■		■	■	■	■											■
Black flounder																						■				■								■

4. DISCUSSION

4.1 Flow limits and habitat protection

4.1.1 Relationships between habitat and flow

One of the aims of this study was to determine the relationship between habitat and flow so that limits on abstraction could potentially be set to maintain habitat integrity in the Wairau Plain springs. Habitat quality for aquatic organisms can depend on a wide range of variables including water quality, cover, substrate type, freedom of access to the sea, flow variability and hydrological variables such as water depth, velocity and wetted width. Only the latter hydrological variables are potentially influenced by spring flows. For example, at Waterlea Creek where there is a good record of multiple flow gaugings, average water depth and width on any particular occasion were closely related with flow (Figure 17). Surprisingly, average water velocity was not related with flow (Figure 17).

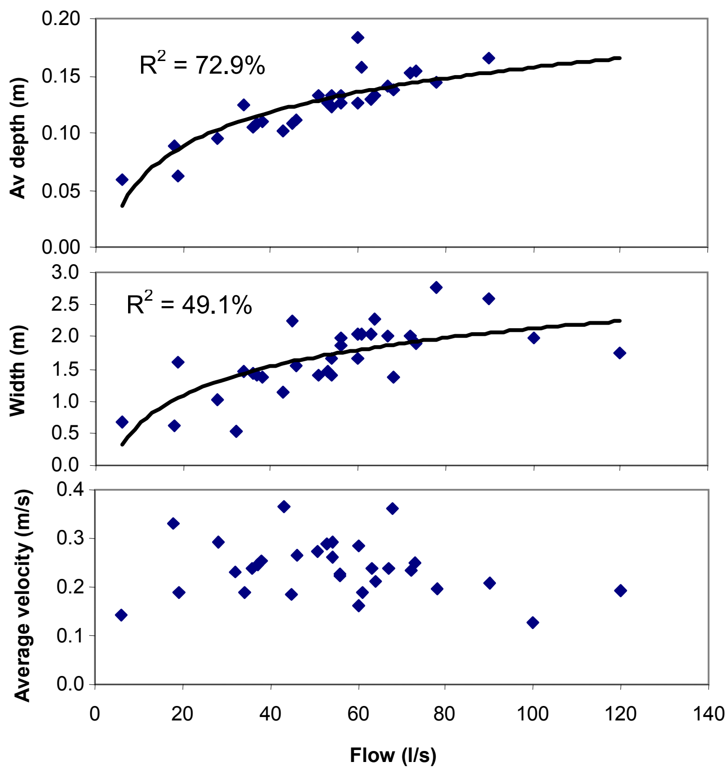


Figure 17 Relationships between flow and hydrological habitat variables at Waterlea Creek.

Flows, however, may not be the only thing controlling water depth, width and velocities. For example, water levels at the Motor Camp site on Spring Creek are thought to be largely dependent on the growth and density of aquatic plants downstream, rather than flow. This is demonstrated in Figure 18 where there was actually a tendency for average depth and width to decrease with flow, rather than increase as would first be expected. It appears that as flow increases in a channel with dense aquatic plant growth the first effect is an increase in water level until eventually the plants are toppled over and water depth decreases. From then on depth slowly increases again with increasing flows. Tidal fluctuation is another factor, independent of flow, which primarily controls water level in the springs near the coast. Similarly, due to the low gradient of many spring-fed streams, water levels may be controlled by the level of the rivers that they flow into rather than their own flows.

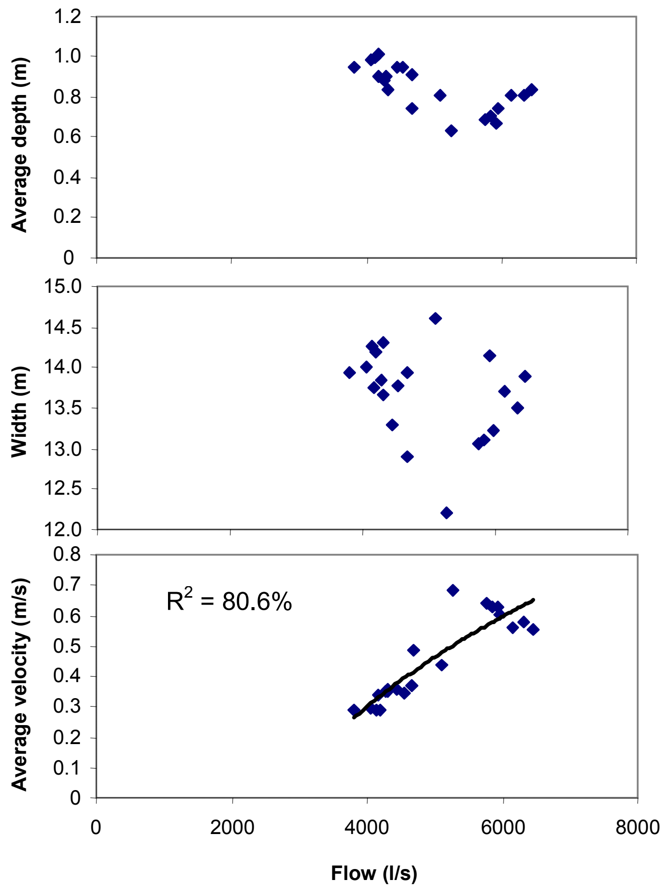


Figure 18 Relationships between flow and hydrological habitat variables at the Motor Camp site on Spring Creek.

4.1.2 Habitat preferences for aquatic organisms

The notion of habitat preference is based upon the idea that species are adapted to a limited range of habitat or environmental conditions. Where habitat or environmental conditions are highly suitable for a particular organism, that organism will often be found in abundance. Hydrological habitat preferences for a variety of species have been defined both in New Zealand and overseas. Relevant suitability curves for fish found in the Wairau Springs are shown in Figure 19 (Hayes & Jowett 1994; Jowett 1995; Bonnett & Sykes 2002). Suitability curves have been developed for some species of macroinvertebrates (Jowett & Richardson 1990), but unfortunately these have concentrated on species that are found in rain-fed gravel-bottomed rivers and can not be applied to species commonly found in spring-fed streams. Most macroinvertebrates that colonise spring-fed streams are those that prefer relatively shallow to moderate depths and slow water velocity.

Most of the fish species found in the Wairau Plain springs prefer slow to intermediate water velocity (0-0.4 m/s) and shallow (10-20 cm) water (Figure 19). Longfin and shortfin eels are habitat generalists and find a variety of environmental conditions to their liking (Figure 19). Giant kokopu tend to like very slow moving water but will occur over a wide depth range. Inanga and common bully prefer shallow water with intermediate water velocity. The suitability curves for adult brown trout shown in Figure 19 are based on measurements from trout feeding on drifting invertebrates and may not be totally appropriate in spring-fed streams where alternative food sources and feeding strategies are probably more important. Nevertheless the curves indicate a preference by adult brown trout for relatively deep water and moderate water velocity (Figure 19).

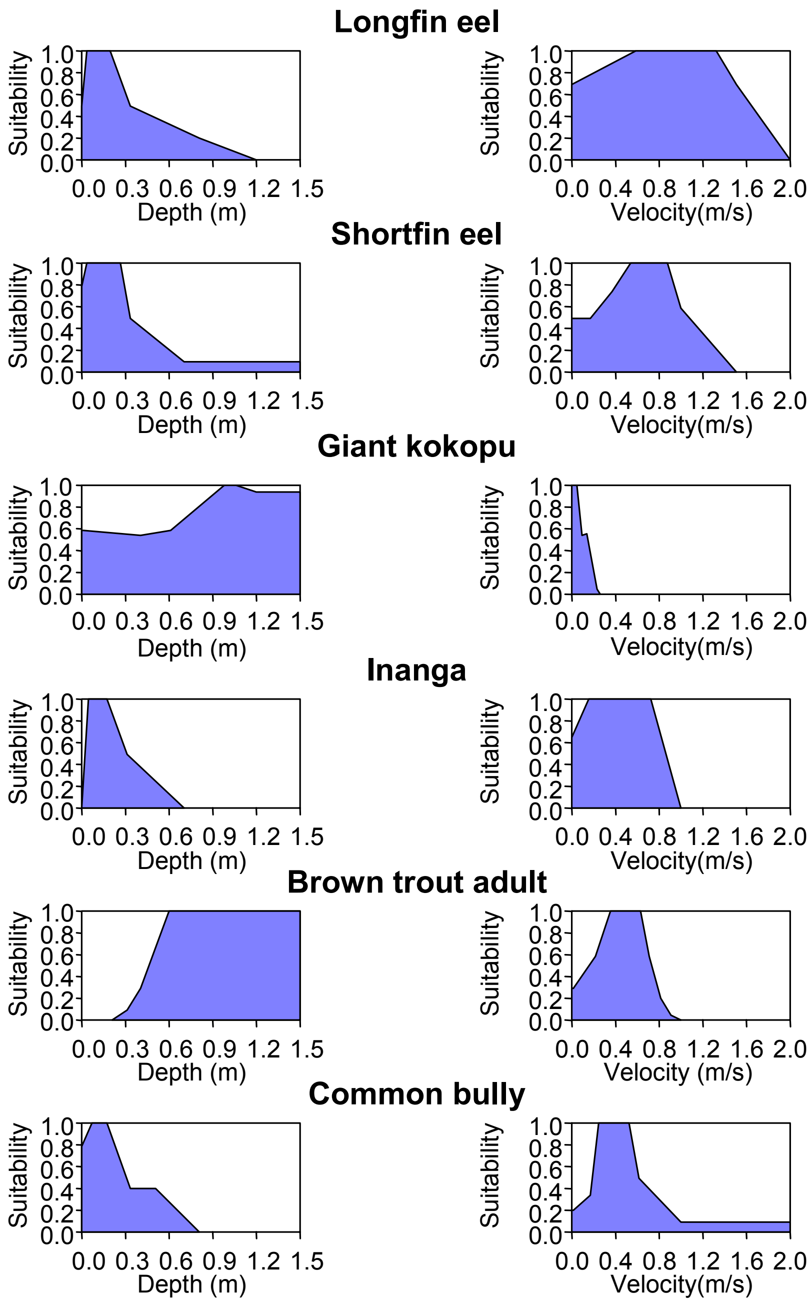


Figure 19 Depth and velocity suitability curves for the main fish species found in the Wairau Plain springs. Suitability is ranked on a scale from 0 to 1.

4.1.3 Historical occurrence of spring drying

Limited available flow data indicated that Doctors, Fairhall and Yelverton dried up during summer 2000/2001. Waterlea may also have dried up (still only 6 l/s in November 2001). The upper reaches of Spring Creek near the Tennis Court were almost dry during early 2001 (R. Young & R.

Strickland, personal observations), whereas water levels in the upper reaches of Murphys were also reported to fluctuate with irrigation pumping. The upper reaches of Caseys, Fultons and the smaller Spring Creek tributaries probably are also threatened by increased groundwater abstraction, along with the upper Grovetown Lagoon tributaries. The upper reaches of Pipitea Nth may also be threatened by abstraction from the shallow Rarangi aquifer if major landuse changes occur there.

4.1.4 Potential strategy on setting limits for habitat protection

Given the data available, the most sensible option for setting limits to protect the habitat in the Wairau Plain spring-fed streams would be to use the flow/habitat relationships from Waterlea Creek (Figure 17) to come up with a trigger level below which irrigation could be restricted. The sheer size of Spring Creek at either the Motor Camp or Gainsford Bridge recording sites, along with the confounding effects of aquatic plant growth on water levels, makes these two sites impractical as potential triggers for managing spring flows.

Once flows in Waterlea drop below 10 l/s, average depth and width are predicted to decline sharply (Figure 17). Presumably water velocity would also decline at about this level although there is insufficient data at low flow to confirm this. As width declines the total area of habitat available will decline, even if the remaining habitat is suitable. At a flow of 10 l/s average depth in Waterlea is predicted to decline to about 5 cm, well below the preferred depth for adult brown trout and in the range of rapid decline in habitat suitability for the other species (Figure 19). Similarly, average velocities at a flow of 10 l/s in Waterlea are probably around 0.15 m/s, which is in the range of declining habitat suitability for all the fish species except shortfin eels and giant kokopu (Figure 19).

The key assumption required in using flows at Waterlea as a trigger to restrict irrigation would be that Waterlea needs to be hydrologically representative of other spring-fed streams threatened by irrigation. Ideally, more flow data from a range of the spring-fed streams would be required to confirm whether this assumption is a good one. However, it may be possible to determine whether this is the case by looking at the relative elevation of each spring-fed stream. Presumably, ‘high’ elevation spring-fed streams would run dry before ‘lower’ elevation ones if groundwater levels are relatively consistent across the Wairau Plain. If Waterlea has a similar or higher elevation to the other threatened springs then it would be a suitable representative. If not then perhaps another spring, such as Yelverton that is likely to dry up first, would be a better ‘early warning’ indicator for abstraction restrictions.

If the above options are unsuitable, or impractical, then another alternative could be to use groundwater levels at Wratts Road Well as a trigger for protection of Spring Creek/Grovetown Lagoon tributaries, while groundwater levels at the Athletic Park Well could be used for protecting the rural and urban Taylor/Opawa spring-fed streams. Relationships between groundwater levels and spring flows would have to be developed before this latter option could be implemented.

4.2 Site rankings

Another aim of this report was to rank the sites in terms of their importance. This is not a simple task since a variety of values must be considered. For example, the urban springs (Murphys, Fultons, Caseys and Waterlea) have considerable aesthetic value, while Drain N & Drain Q have a high biodiversity value due to the presence of giant kokopu. The relative weights to be given to factors such as these really need input from the whole community.

In terms of ecological values, the springs can be ranked as shown in Table 6. These rankings are based on the site groups developed from the water quality and physical data (see section 3.1.1) with some modifications related to the macroinvertebrate and fish communities present at each site. For example, Marukoko is one of the 'red'sites, which generally have poor quality fish and invertebrate communities. However, presumably due to the large amount of flow and easy fish access in Marukoko, biodiversity and ecological values were considered to be good.

Table 6 Ranking of the Wairau Plain springs in terms of their current ecological value. Site colours refer to the groupings from Section 3.1.1.

Ranking	Sites
Good	Drain N, Drain Q, Marukoko, Cravens, Halls, Tennis Courts, O'Dwyers, Hollis, Floodgates
Medium-Good	Kellys, Rapaura, Motor Camp, Collins, Murphys
Medium	Roberts, Grovetown Springs, Fultons, Doctors, Fairhall, Dentons, Caseys, Roses, Waterlea, Pukaka, Yelverton
Medium-Poor	Sadds, Ganes, Woolley & Jones, Town Branch, Riverlands Co-op
Poor	Pipitea Nth, Jeffreys
Very Poor	Riverlands Industrial, Pipitea Sth

5. ACKNOWLEDGEMENTS

We thank Peter Hamill, Ally Jerram and Mike Ede for assistance with the field work and collection of the flow data. Discussions with Peter, Mike and Peter Davidson were also helpful in regard to flow management options. Karen Shearer assisted with the macroinvertebrate sample processing and identification and Aaron Quarterman helped with the report preparation.

6. REFERENCES

Bonnett, M. L.; Sykes, J. R. E. 2002: Habitat preferences of giant kokopu, *Galaxias argenteus*. *New Zealand Journal of Marine & Freshwater Research 36*: 13-24.

Crowe, A. L. M. 2002: Marlborough Macroinvertebrate Monitoring 2000 – 2002. *Cawthron Report No. 736*. 11 p + appendices.

Hayes, J. W.; Jowett, I. G. 1994: Microhabitat models of large drift-feeding brown trout in three New Zealand rivers. *North American Journal of Fisheries Management 14*: 710-725.

Jowett, I. G. 1995: Habitat preferences of common, riverine New Zealand native fishes and implications for flow management. *New Zealand Journal of Marine and Freshwater Research. 29*: 13-24.

Jowett, I. G.; Richardson, J. 1990: Microhabitat preferences of benthic invertebrates in a New Zealand river and the development of in-stream flow-habitat models for *Deleatidium* spp. *New Journal of Marine & Freshwater Research 24*: 19-30.

Stark, J. D. 1985: A macroinvertebrate community index of water quality for stony streams. *Water & Soil Miscellaneous Publication 87*. 53p.

Stark, J. D. 1993: Performance of the macroinvertebrate community index: effects of sampling method, sample replication, water depth, current velocity and substratum on index values. *New Zealand Journal of Marine & Freshwater Research 27*:463-478.

Stark, J. D. 1998: SQMCI: a biotic index for macroinvertebrate coded-abundance data. *New Zealand Journal of Marine & Freshwater Research 32*:55-66.

Young, R. G.; Strickland, R. R.; Harding, J. S.; Stark, J. D.; Hayes, J. W. 2000: The Ecology of Spring Creek - Awarua. Prepared for Marlborough District Council and Fish & Game NZ – Nelson Marlborough Region. *Cawthron Report No. 611*. 52 p plus appendices.

Appendix 1

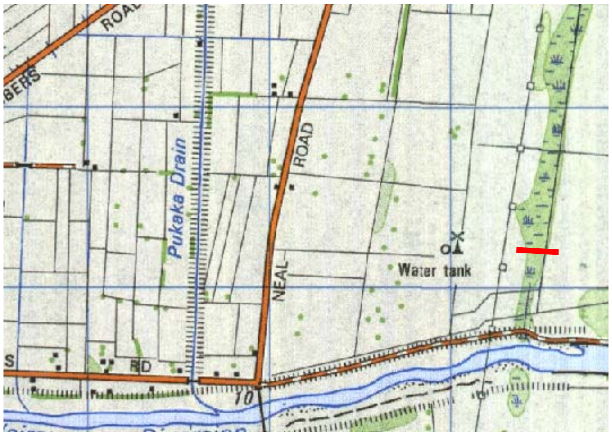
Site Summary Sheets

In this section a short summary of the habitat, water quality and ecology of each site is provided. The location of the cross-section(s) are shown on each map with a red line. The summary sheets are listed in the order we sampled the sites, which is as follows:

Site 1 – Pipitea Nth
Site 2 – Pukaka
Site 3 – Roberts
Site 4 – Sadds
Site 5 – Drain N
Site 6 – Drain Q
Site 7 – Pipitea Sth
Site 8 – Marukoko
Site 9 – Grovetown Springs
Site 10 – Kellys
Site 11 – Waterlea
Site 12 – Fultons
Site 13 – Caseys
Site 14 – Woolley & Jones
Site 15 – Murphys
Site 16 – Doctors
Site 17 – Yelverton
Site 18 – Riverlands Industrial
Site 19 – Riverlands Co-op
Site 20 – Town Branch
Site 21 – Jeffreys
Site 22 – Fairhall
Site 23 – Cravens
Site 24 – Halls

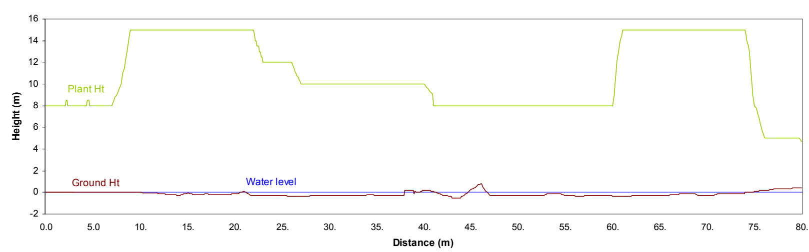
ECOLOGICAL ASSESSMENT - SITE 1 18 March 2002

PIPITEA North



Amongst willows upstream of bridge to new subdivision

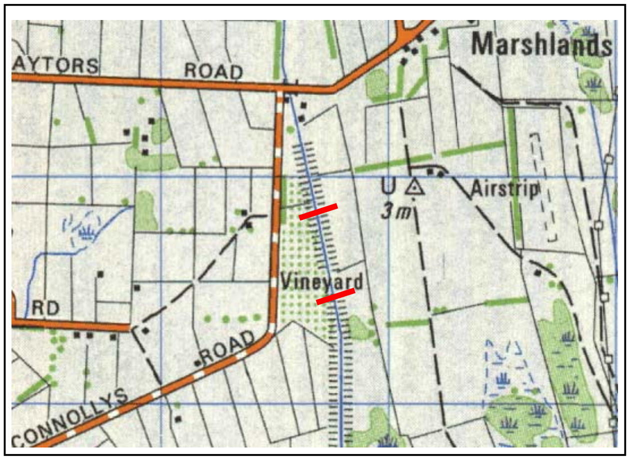
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Wetland with shallow stagnant water and dominated by willows	Lack of flow Dense willow growth suppressing establishment of a diverse under storey	Enhanced through flow to improve water quality and removal of some willows to enhance diversity of plant growth is likely to attract a more diverse fauna	
FISH	Shortfin eels	Anoxic conditions provide limited habitat for fish	Improved water quality and access will increase fish utilisation of this habitat	
AQUATIC PLANT SPECIES	Willow dominated with sparse under storey of flaxes sedges and rushes	Dense willow growth	Diversity of plants on fringe of wetland indicate the potential for more diverse range of plants to establish throughout the wetland with some management of the willows	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 58 SQMCI index = 1.49 EPT taxa = 0 % Species Richness = 9 Dominant taxon = midge larvae (*Chironomus*) Crustacea = not observed	Anoxic conditions and lack of flow restrict the macroinvertebrate fauna to an assemblage of highly tolerant, pond-dwelling taxa.	Improved water quality (particularly DO) may allow more sensitive invertebrates (such as pond-dwelling caddisflies) to inhabit the wetland	
RIPARIAN & BANK PLANT SPECIES	Native shrubs, sedges and variety of weed species		Well stock proofed but some fire damage from surrounding land use	

INSTREAM MICROBIOLOGICAL	*E. coli* = 20 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 441µS/cm pH = 6.8 Dissolved Oxygen = 0.44mg/l (4% saturation) Total Nitrogen = $1.9 g/m^3$ Ammonium-N = $0.22 g/m^3$ Nitrate-N = $0.064 g/m^3$ Total Phosphorus = $0.24 g/m^3$ Dissolved P = $0.22 g/m^3$		Removal of some willows may allow growth of more aquatic plants, which will help to oxygenate the water	
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.3 °C Turbidity = 6.9 NTU Black Disc = 0.9m Total Suspended sediment = $9 g/m^3$ (3 inorganic; 6 organic)			
WATER FLOW	Ungauged – appears to be little water movement			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Rarangi Dune wetland near coast – NZMS 260 P28 955743			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill, Ally Jerram & Mike Ede on 18 March 2002. Fyke nets set overnight. Access from new subdivision road.			

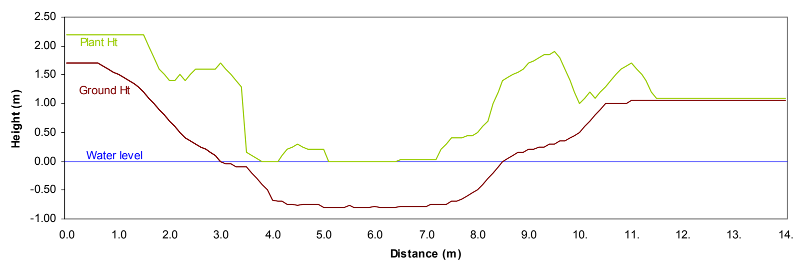
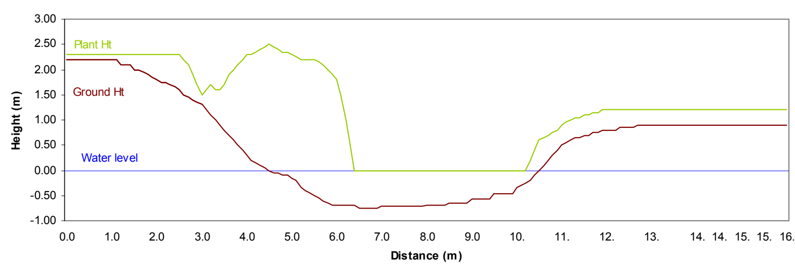
OVERALL ECOLOGICAL ASSESSMENT	**POOR**

ECOLOGICAL ASSESSMENT - SITE 2 **18 March 2002**

PUKAKA



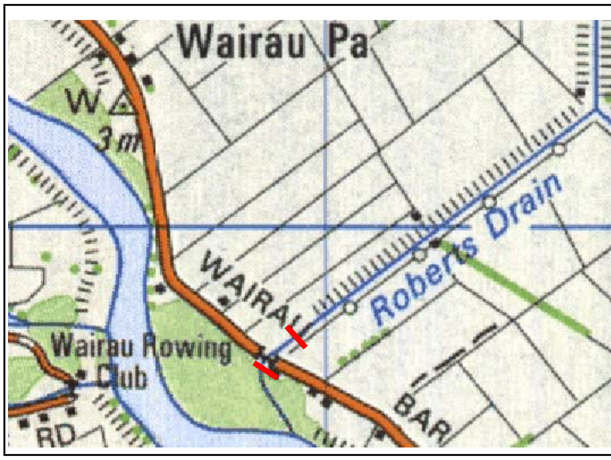
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Highly modified and managed waterway with little water movement	Lack of flow and riparian vegetation	Stream shading and check on means for flow improvement	Surrounding land use may limit opportunities for riparian planting
FISH	Not sampled, but providing there is suitable access, shortfin eels, inanga & common bully should be present	Lack of flow & shade		Fish access should be checked
AQUATIC PLANT SPECIES	Raupo, water cress and duckweed Algae (*Spirogyra* spp.) common	Duckweed suppressing other aquatic plant growth	Increased flow would thin out duckweed and possibly allow establishment of a more diverse range of plants	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 76 SQMCI index = 3.61 EPT taxa = 0 % Species Richness = 11 Dominant taxa = seed shrimps, amphipods, snails Crustacea = seed shrimp & amphipods	Lack of flow, low dissolved oxygen, possible salt water intrusion	Increased flow and dissolved oxygen may allow a more sensitive community to develop, but tidal influxes of salt water may prevent colonisation by EPT taxa	Koura and shrimp have been found in Pukaka Drain on the north side of the Wairau diversion (*i.e.* not connected to this waterbody), just upstream of the floodgates (SoE monitoring site)
RIPARIAN & BANK PLANT SPECIES	Rough pasture, sedges & weed species	No trees		Fenced on LB and no stock access on RB due to vineyards
INSTREAM MICROBIOLOGICAL	*E. coli* = 23 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 342µS/cm pH = 6.9 Dissolved Oxygen = 4.4mg/l (45% saturation)			

	Total Nitrogen = 0.6g/m^3 Ammonium-N = 0.029g/m^3 Nitrate-N = 0.005g/m^3 Total Phosphorus = 0.16g/m^3 Dissolved P = 0.12g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 16.3 °C Turbidity = 4.7 NTU Black Disc = 2.2m Total Suspended sediment = 4 g/m^3 (3 inorganic; 1 organic)			
WATER FLOW	Not gauged - water movement appears to be controlled by tidal movement			
CROSS-SECTION & SUBSTRATE Cross-section 1 at : 2593758 E 5971514 N				
Cross-section 2, upstream				
LOCATION & ZONE	Lower Wairau Plain – large coastal waterway with tidal influence – NZMS 260 P28 937717			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill, Ally Jerram & Mike Ede on 18 March 2002. Access through Chaytors vineyard off Connellys Road			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 3 18 March 2002

ROBERTS



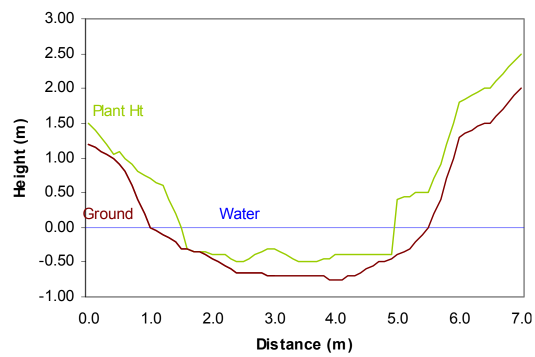
View upstream from bridge

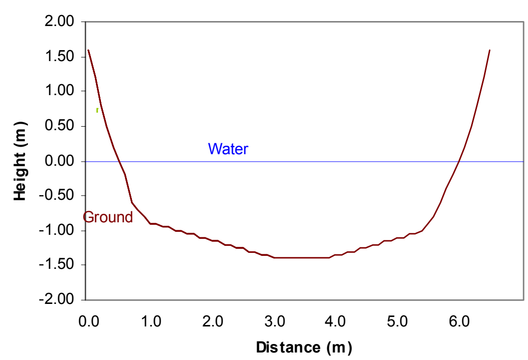
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Good flowing water in a modified waterway with intensive dairy farming in immediate surrounds	Lack of shading, vegetative cover or riparian protection	Bank protection and riparian improvement would enhance fish and wildlife habitat values	
FISH	Good fish habitat because of water quality and includes: shortfin eels, brown trout, inanga, common bully &*Galaxias* spp. (probably giant kokopu)	Lack of riparian protection limits spawning habitat for inanga and general fish habitat	Increased numbers of whitebait and other species possible with better riparian protection	Less intensive aquatic and bankside plant control will increase habitat potential for fish
AQUATIC PLANT SPECIES	Dominated by *Egeria* & *Lagarosiphon* Algae (*Rhizoclonium*)	Intensive control removes all plants	Tree planting may assist in control of nuisance aquatic plant growth	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 77 SQMCI index = 4.80 EPT taxa = 14 % Species Richness = 14 Dominant taxon = amphipods Crustacea = koura, shrimp & amphipods	This good quality macroinvertebrate community was found in a reach with a high density and diversity of aquatic plants. Upstream, the macroinvertebrate community was probably poorer due to removal of all aquatic plants	A good quality macroinvertebrate fauna (as described here) could be present throughout Roberts Drain	Macroinvertebrates were sampled near the floodgates where aquatic plants had not been cleared from the channel
RIPARIAN & BANK PLANT SPECIES	Pasture grasses	Not fenced and stock have unlimited access to stream	Aesthetic and biological gains to be had from stock exclusion and riparian planting	
INSTREAM MICROBIOLOGICAL	*E. coli* = 20 cfu/100 ml			

<table>
<tr><td>INSTREAM CHEMICAL PROPERTIES</td><td>Conductivity = 439µS/cm
pH = 7.0
Dissolved Oxygen = 8.2mg/l (80% saturation)
Total Nitrogen = 0.63g/m^3
Ammonium-N = 0.046g/m^3
Nitrate-N = 0.39g/m^3
Total Phosphorus = 0.024g/m^3
Dissolved P = 0.022g/m^3</td><td></td><td></td><td></td></tr>
<tr><td>INSTREAM PHYSICAL PROPERTIES</td><td>Temperature = 14.7 °C
Turbidity = 2.4 NTU
Black Disc = 2.4 m
Total Suspended sediment = 1 g/m^3 (0.9 inorganic; 0.1 organic)</td><td></td><td></td><td></td></tr>
<tr><td>WATER FLOW</td><td colspan="4">Not gauged – large spring flow going through floodgates or pumped into lower Wairau River</td></tr>
<tr><td>CROSS-SECTION & SUBSTRATE

Cross-section 1: 2592828 E 5969588 N

Cross-section 2, upstream of road bridge</td><td colspan="4">



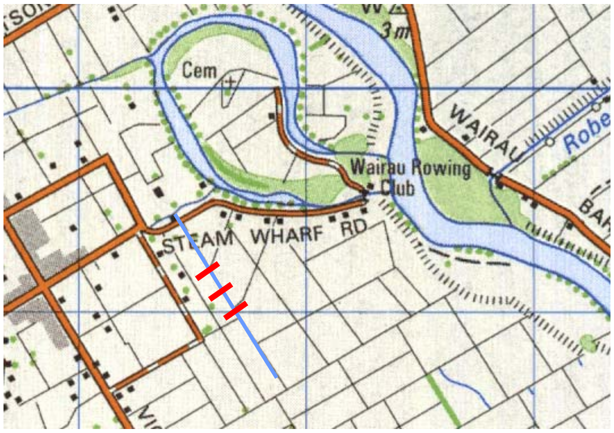


</td></tr>
<tr><td>LOCATION & ZONE</td><td colspan="4">Lower Wairau Plain – large spring-fed rural waterway – NZMS 260 P28 928696</td></tr>
<tr><td>SITE VISIT DETAILS & PERSONNEL</td><td colspan="4">Main survey carried out by Roger Young, Anna Crowe, and Rowan Strickland on 18 March 2002. Spotlight fish survey that night. Access from Wairau Bar Road.</td></tr>
</table>

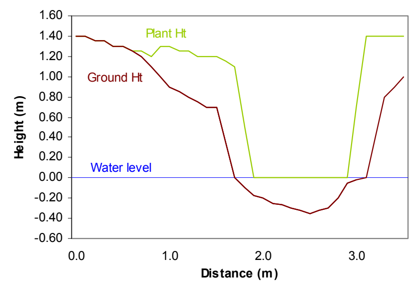
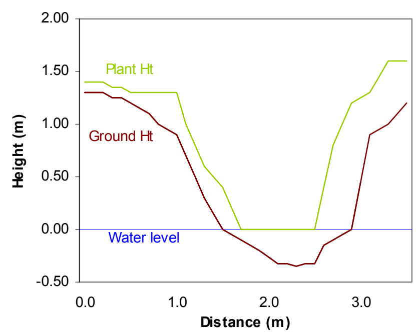
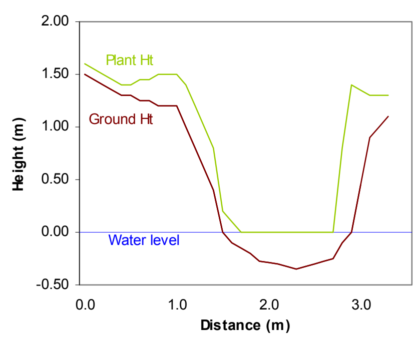
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 4 **19 March 2002**

Sadds



DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Highly modified and unattractive waterway	Intensive surrounding land use, lack of character and riparian protection	Moderate improvement possible with riparian protection	
FISH	Shortfin eels Common bully	As above	As above, but use of this habitat by fish is also very dependant on access	
AQUATIC PLANT SPECIES	Duckweed	Lack of flow prevents dispersal of floating plants and the establishment of other plants		Dense growth of duckweed helps suppress growth of nuisance plants
MACROINVERTEBRATES & CRUSTACEA	MCI index = 91 SQMCI index = 2.30 EPT taxa = 0 % Species Richness = 14 Dominant taxon = worms Crustacea = not observed	Lack of flow limits macroinvertebrate fauna to 'pond-dwelling' taxa High turbidity, low dissolved oxygen	Increases in flow will improve habitat for EPT and crustacean taxa	
RIPARIAN & BANK PLANT SPECIES	Fenced TR bank with grasses and sedges, but stock access on TL with bare soil and grazed pasture	No protection on TL bank	Fencing and planting	Shading and cover provided by grasses and sedges on fenced TR bank
INSTREAM MICROBIOLOGICAL	*E. coli* = 140 cfu/100 ml	No protection on TL bank	Fencing and planting	Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 103µS/cm pH = 6.4 Dissolved Oxygen = 7.1mg/l (67% saturation) Total Nitrogen = 0.81g/m^3			

	Ammonium-N = 0.044g/m^3 Nitrate-N = 0.48g/m^3 Total Phosphorus = 0.038g/m^3 Dissolved P = 0.013g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 12.8 °C Turbidity = 5.6 NTU Total Suspended sediment = 2 g/m^3 (1 inorganic; 1 organic)			
WATER FLOW	Not gauged – water levels probably linked with levels in Grovetown Lagoon.			
CROSS-SECTION & SUBSTRATE Cross-section 1: 2591610 E 5969157 N (up stream)				
Cross-section 2 (middle site)				
Cross-section 3 (down stream)				
LOCATION & ZONE	Lower Wairau Plain – small rural waterway – NZMS 260 P28 916691			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 19 March 2002. Access off Steam Wharf road.			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-POOR**

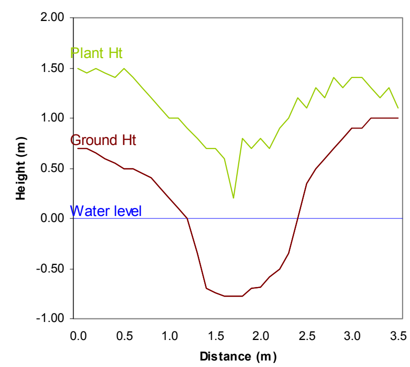
ECOLOGICAL ASSESSMENT - SITE 5 19 March 2002

DRAIN N

View downstream from road

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Highly modified waterway with intensive surrounding land use, but good flow	Surrounding land use and close proximity to public road	Good wildlife and fish habitat but requires careful management of riparian zone	
FISH	Giant kokopu, Longfin eels, Shortfin eels, Common bully, Brown trout, Inanga	As above and lack of habitat diversity		Already used by greater range of species than most other sites, but habitat could be better managed
AQUATIC PLANT SPECIES	Duckweed Willow weed Watercress			Encouragement of overhanging pasture grasses and planting of shrubs would help shade drain and control aquatic plants
MACROINVERTEBRATES & CRUSTACEA	MCI index = 94 SQMCI index = 3.90 EPT taxa = 29 % Species Richness = 21 Dominant taxon = snails (*Potamopyrgus*) Crustacea = koura and amphipods			Good quality macroinvertebrate community was present Encouragement of overhanging pasture grasses would provide good habitat for Crustacea
RIPARIAN & BANK PLANT SPECIES	Bound by vineyards and road with very small riparian zone of mown and un mown grasses	Small riparian zone and land use limits planting opportunity	Flaxes and low shrubs would provide good riparian protection and stream shade.	Indiscriminate use of herbicides and mowing of riparian zone
INSTREAM MICROBIOLOGICAL	*E. coli* = 70 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 90µS/cm pH = 6.5			

<table>
<tr><td></td><td>Dissolved Oxygen = 5.6mg/l (54% saturation)
Total Nitrogen = 0.75g/m^3
Ammonium-N = 0.011g/m^3
Nitrate-N = 0.38g/m^3
Total Phosphorus = 0.022g/m^3
Dissolved P = 0.01g/m^3</td><td></td><td></td><td></td></tr>
<tr><td>INSTREAM PHYSICAL PROPERTIES</td><td>Temperature = 13.7 °C
Turbidity = 0.8 NTU
Total Suspended sediment = 0.6 g/m^3 (0 inorganic; 0.6 organic)</td><td></td><td></td><td></td></tr>
<tr><td>WATER FLOW</td><td colspan="4">Flow gauged by Mike Ede on 19 March 2002= 30 l/s</td></tr>
<tr><td>CROSS-SECTION & SUBSTRATE

Cross-section 1: 2589492 E 5969500 N (Northern side of road)</td><td colspan="4">
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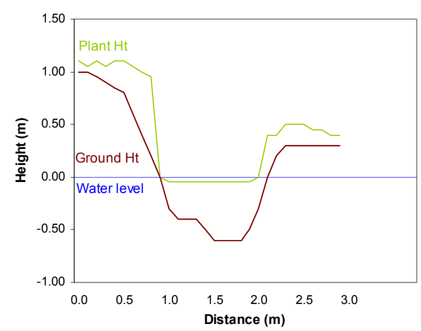
<tr><td>Cross-section 2</td><td colspan="4">
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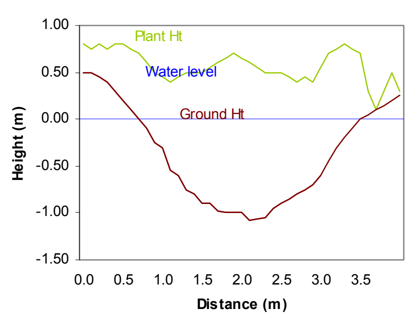
<tr><td>Cross-section 3 : 2589527 E 5969468 N (down stream site)</td><td colspan="4">
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LOCATION & ZONE	Upper Grovetown Lagoon tributary – small rural spring - NZMS 260 P28 895695
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 19 March 2002. Spotlight fish survey carried out that night. Access from Mills & Ford road

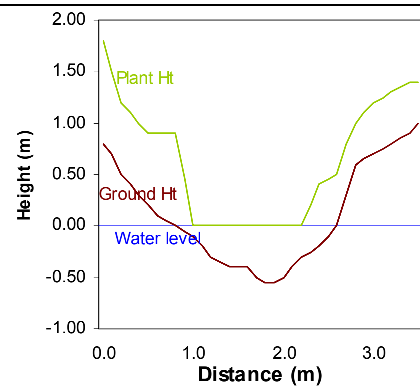
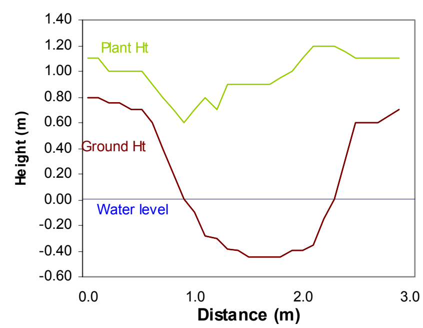
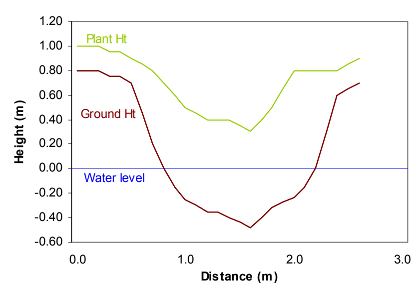
OVERALL ECOLOGICAL ASSESSMENT	**GOOD**

ECOLOGICAL ASSESSMENT - SITE 6 19 March 2002

DRAIN Q

View looking back towards road

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Small modified waterway with good flow	Surrounding land use and close proximity to public road	Good fish habitat but requires careful management of riparian zone	
FISH	Giant kokopu, Shortfin eels, Common bully	Habitat diversity lacking in reach alongside road	As above	
AQUATIC PLANT SPECIES	Duckweed Watercress	Regular control	Diversity of good aquatic plants possible without becoming a nuisance	Requires shade plantings to reduce the need for control and habitat disturbance
MACROINVERTEBRATES & CRUSTACEA	MCI index = 83 SQMCI index = 3.72 EPT taxa = 8 % Species Richness = 24 Dominant taxon = snails (*Potamopyrgus*) Crustacea = koura, amphipods and seed shrimp	Habitat diversity lacking in reach alongside road, regular aquatic plant control	Further colonisation by EPT taxa as seen in Drain N, particularly mayflies and increased diversity of caddisfly species	
RIPARIAN & BANK PLANT SPECIES	Mix of horticulture, mown lawn and mown road verge	Residential and road verge	Enhancement of some portions of riparian zone possible through planting shrubs	Mowing and herbicide control of riparian vegetation reduces shading potential
INSTREAM MICROBIOLOGICAL	*E. coli* = 55 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 86μS/cm pH = 6.4 Dissolved Oxygen = 7.3mg/l (71% saturation) Total Nitrogen = 0.68g/m^3			

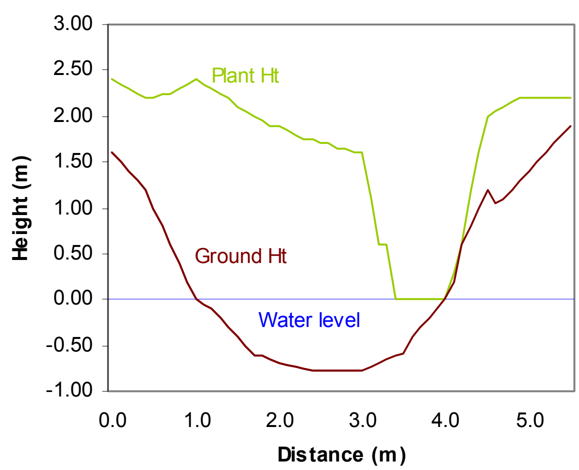
	Ammonium-N = 0.021g/m^3 Nitrate-N = 0.46g/m^3 Total Phosphorus = 0.019g/m^3 Dissolved P = 0.016g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 14.1 °C Turbidity = 1.7NTU Black Disc = 3.5m Total Suspended sediment = 1 g/m^3 (0.6 inorganic; 0.4 organic)			
WATER FLOW	Flow gauged by Mike Ede on 19 March 2002= 6 l/s			
CROSS-SECTION & SUBSTRATE Cross-section 1: 2590103 E 5969853 N (down stream site) Cross-section 2 : 2590052 E 5969907 N (middle site) Cross-section 3, 5 m upstream	  			
LOCATION & ZONE	Upper Grovetown Lagoon tributary – small rural spring - NZMS 260 P28 901699			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 19 March 2002. Spotlight fish survey carried out that night. Access from Mills & Ford road			
OVERALL ECOLOGICAL ASSESSMENT		**GOOD**		

ECOLOGICAL ASSESSMENT - SITE 7 **19 March 2002**

PIPITEA South

View upstream from floodgate

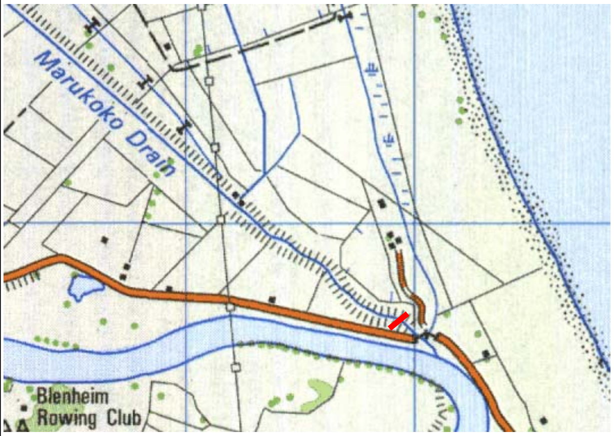
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified and deep waterway with very little flow	Floodgate prevents adequate flushing of the waterway	Very good potential to improve the biological value of this site by different management of floodgate	
FISH	No fish at sample site, but Yelloweye mullet and inanga observed below floodgate	Floodgate prevents access and its closure creates anoxic conditions upstream	Unique habitat for inanga and other migratory species if continuous access from Wairau River was made available	Small change in floodgate management has potential for significant enhancement of whitebait numbers
AQUATIC PLANT SPECIES	Duckweed Raupo	Inadequate flow and flushing	More diversity of plant species with better flow and less duckweed	Nuisance plant growth in lower reaches would be limited if more saltwater intrusion was allowed
MACROINVERTEBRATES & CRUSTACEA	Not sampled but impoverished fauna observed	Inadequate flow and flushing creates anoxic conditions	Healthy estuarine community would develop with increased flushing / saltwater intrusion	
RIPARIAN & BANK PLANT SPECIES	Grazed pasture to crest of waterway on both banks	No permanent stock exclusion	Potential for riparian management and planting	
INSTREAM MICROBIOLOGICAL	*E. coli* = 10 cfu/100 ml			

INSTREAM CHEMICAL PROPERTIES	Conductivity = 1050µS/cm pH = 6.4 Dissolved Oxygen = 0.5mg/l (6% saturation) Total Nitrogen = 1.3g/m^3 Ammonium-N = 0.26g/m^3 Nitrate-N = 0.014g/m^3 Total Phosphorus = 0.28g/m^3 Dissolved P = 0.18g/m^3	Little flow	Increased flushing would help by improving oxygen levels	
INSTREAM PHYSICAL PROPERTIES	Temperature = 14 °C Turbidity = 22 NTU Total Suspended sediment = 20 g/m^3 (11 inorganic; 9 organic)			
WATER FLOW	Not gauged – water level controlled by tidal fluctuation and Wairau River levels. Flushing restricted by floodgate.			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Lower Wairau Plain – near coast with tidal influence - NZMS 260 P28 961687			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 19 March 2002. Access through farm off Wairau Bar Road.			

OVERALL ECOLOGICAL ASSESSMENT	**VERY POOR**

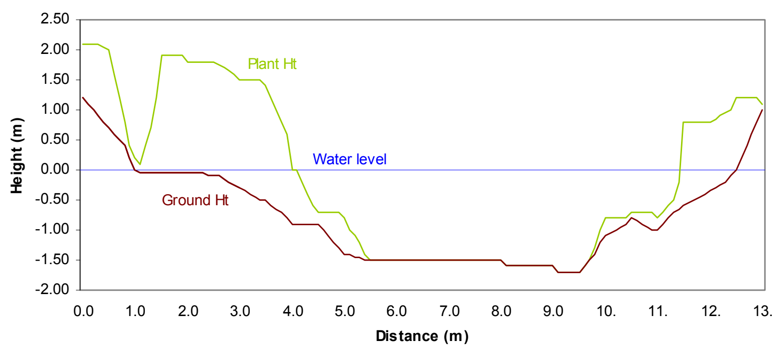
ECOLOGICAL ASSESSMENT - SITE 8 19 March 2002

MARUKOKO



View upstream from Wairau Bar Road

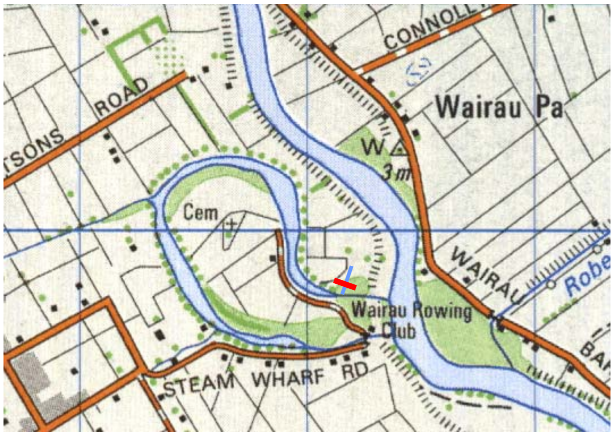
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Larger of the spring fed waterways, providing good wildlife and fish habitat	Flap gate control and lack of riparian management	Habitat enhancement opportunities	
FISH	Longfin eels Shortfin eels Inanga Common bully	As above and stock exclusion	Unique habitat for inanga, but would benefit from riparian management and continuous access from Wairau River	
AQUATIC PLANT SPECIES	*Nitella* and mixed aquatic plant species Algae (*Enteromorpha*) common	Saltwater intrusion, but controls nuisance species in lower reaches		
MACROINVERTEBRATES & CRUSTACEA	MCI index = 68 SQMCI = 4.04 EPT taxa = 17 % Species Richness = 12 Dominant taxon = snails (*Potamopyrgus*) Crustacea = amphipods present	Saltwater intrusion limits colonisation by some of the more sensitive freshwater macroinvertebrates		
RIPARIAN & BANK PLANT SPECIES	Pasture, sedges, scrub and raupo	No stock exclusion	Fencing and planting	Plenty of scope for enhancement
INSTREAM MICROBIOLOGICAL	*E. coli* = 210 cfu/100 ml Above contact guidelines		Restrict stock access and runoff	
INSTREAM CHEMICAL PROPERTIES	Conductivity = 1018µS/cm pH = 8.0			

	Dissolved Oxygen = 13.5mg/l (141% saturation) Total Nitrogen = 0.71g/m^3 Ammonium-N = 0.012g/m^3 Nitrate-N = 0.004g/m^3 Total Phosphorus = 0.44g/m^3 Dissolved P = 0.37g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.6 °C Turbidity = 6.3 NTU Total Suspended sediment = 20 g/m^3 (16 inorganic; 4 organic)			
WATER FLOW	Not gauged – large spring flow influenced by tidal fluctuations and river levels			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Lower Wairau Plain – large waterway near coast with tidal influence - NZMS 260 P28 959686			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 19 March 2002. Spotlight fish survey carried out that night. Fyke nets also set. Access from Wairau Bar road.			

OVERALL ECOLOGICAL ASSESSMENT	**GOOD**

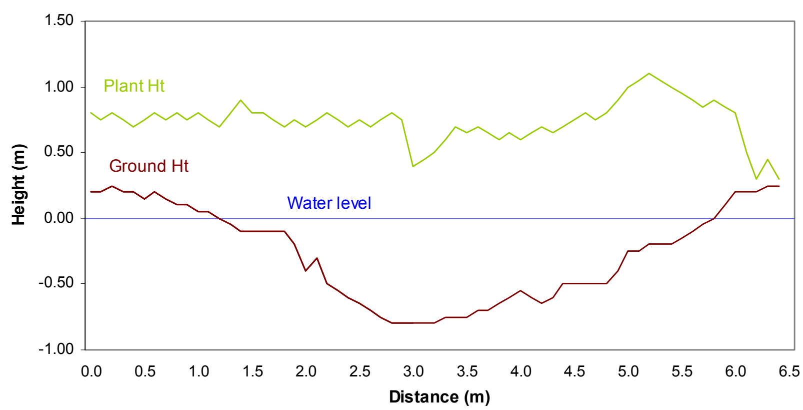
ECOLOGICAL ASSESSMENT - SITE 9 **20 March 2002**

GROVETOWN LAGOON SPRINGS



Looking back towards the lagoon

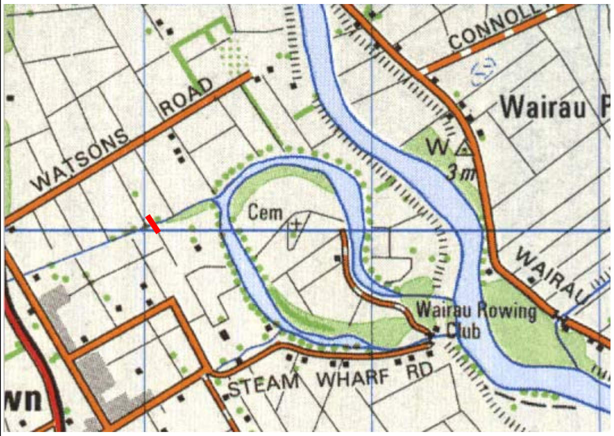
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Manmade waterway for intercepting small springs draining into lower end of Grovetown lagoon	Short course, grazed on both sides, prolific aquatic plant growth	Shade trees may assist in control of excessive aquatic plant growth	Shade experiment being conducted in lower end by MDC
FISH	Shortfin eel Inanga Common bully	As above	Enhancement of habitat possible through riparian planting and natural control of plants	Good fish habitat but in the absence of riparian cover, aquatic plants are an essential component of the habitat
AQUATIC PLANT SPECIES	*Glyceria maxima* Willow weed Watercress Algae (*Spirogyra*; *Vaucheria*)			Potentially good local source of watercress depending on controls implemented, although bacterial levels are of concern
MACROINVERTEBRATES & CRUSTACEA	MCI index = 87 SQMCI index = 4.46 EPT taxa = 7 % Species Richness = 15 Dominant taxa = snails (*Potamopyrgus*), amphipods Crustacea = amphipods & shrimp present			Aquatic plant growth provides good habitat for freshwater shrimp
RIPARIAN & BANK PLANT SPECIES	Rough pasture, rushes and sedges	Not stock proofed and no trees	Fencing, planting and reversion to a more natural wetland	
INSTREAM MICROBIOLOGICAL	*E. coli* = 1200 cfu/100 ml	Stock access	Restrict stock access and any runoff	Well above contact guidelines

INSTREAM CHEMICAL PROPERTIES	Conductivity = 150µS/cm pH = 6.6 Dissolved Oxygen = 6.3mg/l (61% saturation) Total Nitrogen = 0.48g/m^3 Ammonium-N = 0.008g/m^3 Nitrate-N = 0.25g/m^3 Total Phosphorus = 0.019g/m^3 Dissolved P = 0.012g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 14.1 °C Turbidity = 0.9 NTU Total Suspended sediment = 0.8 g/m^3 (0.3 inorganic; 0.5 organic)			
WATER FLOW	Not gauged moderate spring flow. Water levels probably controlled by level of Grovetown Lagoon.			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Grovetown Lagoon tributary – small rural spring - NZMS 260 P28 922698			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 20 March 2002. Access from Steam Wharf road.			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 10 20 March 2002

KELLYS

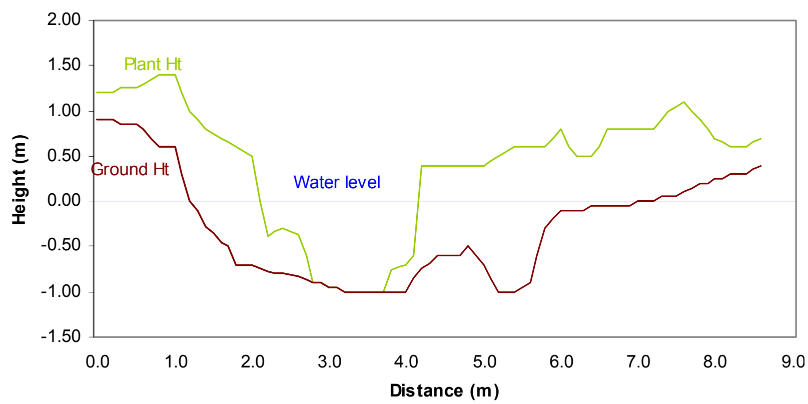


Looking downstream

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Good flow and clear water	Unfenced and shaded on North side	Scope for enhancement	
FISH	Shortfin eel Common bully Inanga Brown trout	Access controlled by floodgate operation in lagoon downstream	Good fish habitat if riparian zone is managed carefully	Fish use is likely to increase with improved access and minimised control disturbance
AQUATIC PLANT SPECIES	Willow weed, *Egeria*, *Elodea*, *Lagarosiphon* Algae (*Spirogyra*; *Oscillatoria*)	Controlled from north side	Shade trees on north side would decrease the necessity for control works	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 87 SQMCI index = 3.66 EPT taxa = 33 % Species Richness = 24 Dominant taxon = snails (*Potamopyrgus*) Crustacea = koura, amphipods & seed shrimp present			
RIPARIAN & BANK PLANT SPECIES	Dairy grazing to stream side on TL bank, but fenced with overhanging willows on TR	Stock access	Enhancement and aquatic plant control potential with fencing and riparian planting	
INSTREAM MICROBIOLOGICAL	*E. coli* = 540 cfu/100 ml	Stock access and perhaps septic tanks	Requires improvements in restriction of stock access throughout this relatively large catchment Checks on septic tank inputs.	Above contact guidelines

INSTREAM CHEMICAL PROPERTIES	Conductivity = 117µS/cm pH = 6.9 Dissolved Oxygen = 8.8mg/l (88% saturation) Total Nitrogen = 0.77g/m^3 Ammonium-N = 0.016g/m^3 Nitrate-N = 0.46g/m^3 Total Phosphorus = 0.037g/m^3 Dissolved P = 0.027g/m^3	Stock access	Riparian fencing and planting	
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.1 °C Turbidity = 4.1 NTU Black Disc = 2.5 m Total Suspended sediment = 3 g/m^3 (2 inorganic; 1 organic)			
WATER FLOW	Gauged on 19th July 1991 = 280 l/s			

CROSS-SECTION & SUBSTRATE

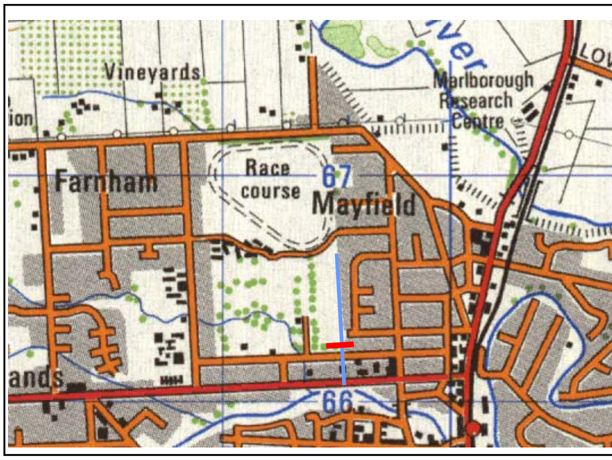


LOCATION & ZONE	Main Grovetown Lagoon tributary – large rural spring - NZMS 260 P28 910700
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 20 March 2002. Access through farm off Steam Wharf road.

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-GOOD**

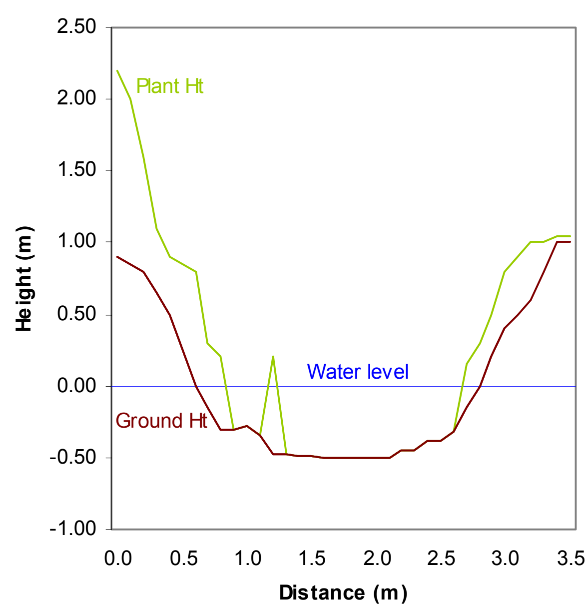
ECOLOGICAL ASSESSMENT - SITE 11 **20 March 2002**

WATERLEA



View upstream alongside golf course

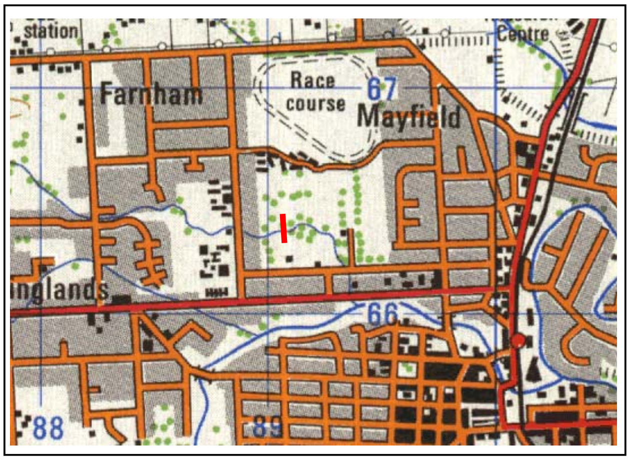
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified urban stream with fish access problems	Surrounding land use, lack of character and riparian protection	Habitat enhancement and improved fish access	
FISH	Shortfin eels only at this site, but shortfin eels, inanga, common bully and longfin eels downstream	Waterway upstream of road culvert, weir and flap gate inaccessible to some species	As above	
AQUATIC PLANT SPECIES	*Lagarosiphon* and other plants hand weeded	Regular indiscriminate control	More habitat would be provided by selective control of aquatic plants	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 88 SQMCI index = 3.08 EPT taxa = 20 % Species Richness = 25 Dominant taxa = seed shrimp & worms Crustacea = koura, shrimp, amphipods & seed shrimp	Aquatic plant removal High turbidity	Selective control of aquatic plants and encouragement of overhanging riparian plantings would increase habitat for the diverse crustacean fauna	Species richness, crustacean and EPT taxa diversity was high
RIPARIAN & BANK PLANT SPECIES	Mown lawn to waterway crest and some residential fencing with occasional shrubs	Surrounding land use	More bankside shrub species for shade and cover could be planted	Any planting will enhance the aesthetics of this waterway
INSTREAM MICROBIOLOGICAL	*E. coli* = 380 cfu/100 ml	Leaky septic tanks? Urban runoff		Above contact guidelines

INSTREAM CHEMICAL PROPERTIES	Conductivity = 130µS/cm pH = 6.8 Dissolved Oxygen = 8.2mg/l (85% saturation) Total Nitrogen = 1.9g/m^3 Ammonium-N = 0.012g/m^3 Nitrate-N = 1.3g/m^3 Total Phosphorus = 0.034g/m^3 Dissolved P = 0.024g/m^3	High groundwater nitrate		High nitrogen levels
INSTREAM PHYSICAL PROPERTIES	Temperature = 17.0 °C Turbidity = 7.4 NTU Black Disc = 1.4 m Total Suspended sediment = 4 g/m^3 (3 inorganic; 1 organic)			
WATER FLOW	Flow gauged by Mike Ede = 54 l/s Weekly gauging carried out here since October 2001- range 6-120 l/s			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Springlands urban spring-fed stream - NZMS 260 P28 895662			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 20 March 2002. Access beside golf course.			

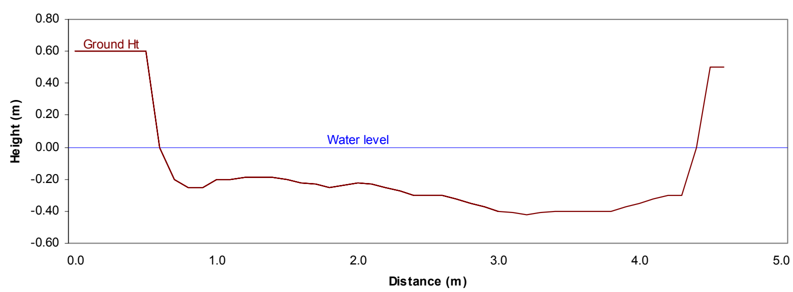
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 12 20 March 2002

FULTONS



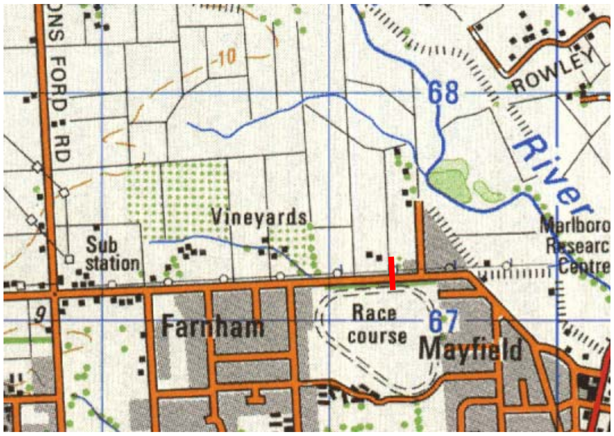
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Urban watercourse modified as a park feature	Managed as a water feature rather than for biodiversity	Aesthetics and habitat values could be enhanced	
FISH	Longfin eels, Shortfin eels, Common bully, Brown trout, Inanga	Instream cover	Better instream habitat could be provided by fostering some aquatic plants	
AQUATIC PLANT SPECIES	Only remnants of *Elodea*, *Lagarosiphon, Glyceria, Nitella* and watercress	Indiscriminate hand weeding of entire watercourse through park	Selective hand weeding of nuisance plants only would improve the aesthetic and habitat values of this stream	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 87 SQMCI = 3.40 EPT taxa = 28 % Species Richness = 18 Dominant taxa = amphipods, worms, snails (*Potamopyrgus*) Crustacea = koura, amphipods & seed shrimp	As above	Better instream habitat could be provided by fostering some aquatic plants	
RIPARIAN & BANK PLANT SPECIES	Mown lawns to concrete and rock bank lining	Park management objectives	Additional values possible with enhancement programme	
INSTREAM MICROBIOLOGICAL	*E. coli* = 140 cfu/100 ml	Urban runoff		Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 145µS/cm pH = 6.3 Dissolved Oxygen = 6.9mg/l (69% saturation)	High groundwater nitrate		High nitrogen levels

	Total Nitrogen = 3.6g/m^3 Ammonium-N = 0.01g/m^3 Nitrate-N = 2.6g/m^3 Total Phosphorus = 0.016g/m^3 Dissolved P = 0.015g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.2 °C Turbidity = 1.7 NTU Black Disc = 5.0m Total Suspended sediment = 2 g/m^3 (1 inorganic; 1 organic)			
WATER FLOW	Gauged on 22 March 2002 by Mike Ede = 299 l/s Also gauged 3 December 1999 (272 l/s) and 14 June 2001 (230 l/s)			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Springlands large urban spring-fed stream - NZMS 260 P28 890664			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 20 March 2002. Spotlight fish survey carried out that night. Access through park.			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

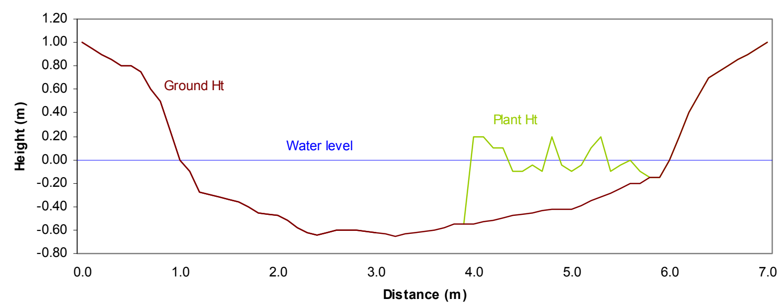
ECOLOGICAL ASSESSMENT - SITE 13 20 March 2002

Caseys



Looking south along Old Renwick road

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified watercourse with good flow and clear water	Surrounding land use and close proximity to public road	Habitat enhancement planting on roadside	
FISH	Shortfin eels Brown trout Inanga	Road verge management and removal of bankside vegetation	Increase cover through provision of bankside vegetation	
AQUATIC PLANT SPECIES	*Lagarosiphon*, Willow weed, Duckweed, Water cress	Control	Control reduction possible with more bankside shading	Shading on TL is already effective in reducing aquatic plant growth
MACROINVERTEBRATES & CRUSTACEA	MCI index = 85 SQMCI index = 4.33 EPT taxa = 19 % Species Richness = 21 Dominant taxa = amphipods, snails (*Potamopyrgus*) Crustacea = koura, amphipods & seed shrimp	Removal of bankside vegetation	Encouragement of overhanging bankside vegetation would increase habitat for Crustacea	
RIPARIAN & BANK PLANT SPECIES	Mown grass verge on TR and hedge and shelter belt plantings along TL	Road verge management	Low shrubs for bankside cover	Discourage use of herbicide control of bankside vegetation
INSTREAM MICROBIOLOGICAL	*E. coli* = 80 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 129µS/cm pH = 6.3 Dissolved Oxygen = 7.9mg/l (80% saturation)	High groundwater nitrate levels		

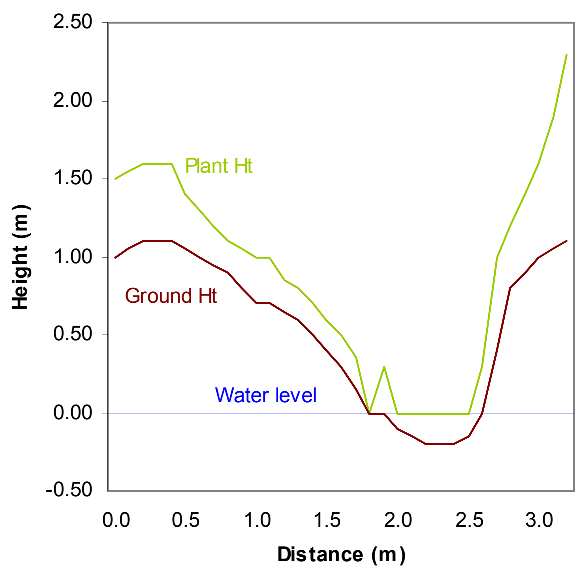
	Total Nitrogen = 2.4g/m^3 Ammonium-N = 0.02g/m^3 Nitrate-N = 1.7g/m^3 Total Phosphorus = 0.015g/m^3 Dissolved P = 0.015g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.9 °C Turbidity = 1.4 NTU Black Disc = 5.0m Total Suspended sediment = 1 g/m^3 (0.9 inorganic; 0.1 organic)			
WATER FLOW	Not gauged			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Springlands urban spring-fed stream - NZMS 260 P28 893672			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 20 March 2002. Spotlight fish survey carried out that night. Access from Old Renwick road			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 14 21 March 2002

WOOLLEY & JONES

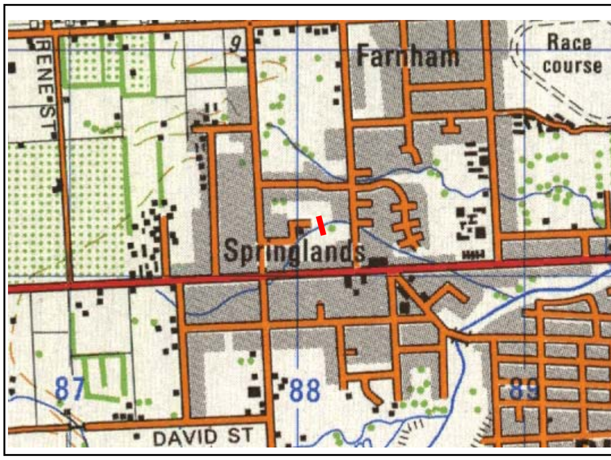
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Small spring flow contained within farm drainage system	Size	Habitat enhancement opportunity by fencing and planting	
FISH	Shortfin eels Good eel cover provided by overhanging bankside vegetation	Access for other species dependant on floodgate operation		
AQUATIC PLANT SPECIES	Almost 100% cover of duckweed	Small flow		
MACROINVERTEBRATES & CRUSTACEA	MCI index = 74 SQMCI = 1.77 EPT taxa = 0 % Species Richness = 16 Dominant taxa = worms, midge larvae (*Chironomus*) Crustacea = amphipods & seed shrimp	Low flow velocity, low dissolved oxygen, little aquatic plant diversity	Any increases in flow will improve DO and quality of the macroinvertebrate community Increased aquatic plant diversity would increase macroinvertebrate habitat	Overhanging bankside vegetation provides some habitat for macroinvertebrates
RIPARIAN & BANK PLANT SPECIES	Rough pasture in immediate riparian zone with fenced TR bank and hedge of macrocarpa, hawthorn etc	Surrounding land use		In the absence of riparian tree planting on TL bank, overhanging vegetation is important habitat
INSTREAM MICROBIOLOGICAL	*E. coli* = 20 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 249µS/cm pH = 6.7 Dissolved Oxygen = 2.0mg/l (22% saturation)	Little flow Agricultural runoff Stock access	Riparian fencing and planting	

	Total Nitrogen = 1.3g/m^3 Ammonium-N = 0.26g/m^3 Nitrate-N = 0.19g/m^3 Total Phosphorus = 0.16g/m^3 Dissolved P = 0.054g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 18.2 °C Turbidity = 2.7 NTU Total Suspended sediment = 5 g/m^3 (4 inorganic; 1 organic)	Little shade on north bank Weak connection with the aquifer	Plantings	
WATER FLOW	Not gauged			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Lower Wairau Plain – small rural waterway - NZMS 260 P28 922682			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 21 March 2002. Access through farm off Jones road.			

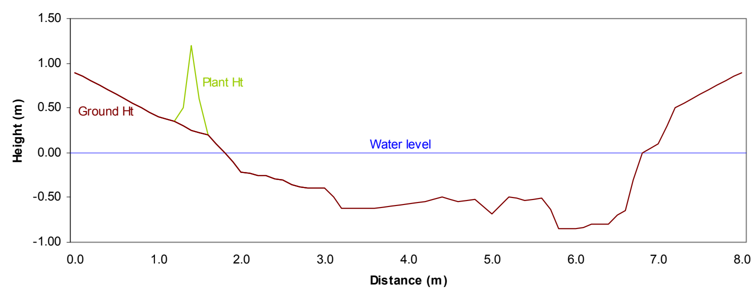
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-POOR**

ECOLOGICAL ASSESSMENT - SITE 15 **21 March 2002**

MURPHYS



DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	One of the larger urban spring fed streams	Close proximity of residential properties and possible riparian rights		Aesthetic values important to the many residential properties developed to incorporate the stream in their development
FISH	Brown trout Common bully Longfin eels Shortfin eels Inanga	Good fish habitat but would be improved with less disturbance from aquatic plants control	Better instream habitat could be provided by selective hand weeding of aquatic plants	In settings such as the park and retirement village opposite, viewing and feeding platforms could be made where eels, other fish or waterfowl could be tamed as a feature
AQUATIC PLANT SPECIES	*Lagarosiphon*, Watercress, *Glyceria*	Indiscriminate control Perception of all aquatic plants as nuisance	Aesthetic and habitat values could be enhanced by allowing non-nuisance plants to establish	Scope for aquatic plant growth to become a feature
MACROINVERTEBRATES & CRUSTACEA	MCI index = 68 SQMCI = 1.64 EPT taxa = 17 % Species Richness = 12 Dominant taxon = worms Crustacea = amphipods & seed shrimp present	Indiscriminate control of aquatic plants Little overhanging streamside vegetation	Increased aquatic plant growth would improve habitat for macroinvertebrates, and would allow more sensitive taxa to inhabit and dominate the community	Koura have been found in low abundance near confluence with the Taylor River (at the SoE monitoring site)
RIPARIAN & BANK PLANT SPECIES	Some bankside trees and natural low vegetation such as sedges and willow weed, but mostly made up of mixed garden styles and mown lawns	Land ownership Differing views on aesthetics	Recommend streamside planting regimes for more effective habitat enhancement	

INSTREAM MICROBIOLOGICAL	*E. coli* = 140 cfu/100 ml	Urban runoff		Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 155µS/cm pH = 6.0 Dissolved Oxygen = 8.1mg/l (78% saturation) Total Nitrogen = 4.6g/m^3 Ammonium-N = 0.007g/m^3 Nitrate-N = 3.2g/m^3 Total Phosphorus = 0.016g/m^3 Dissolved P = 0.015g/m^3	High groundwater nitrate levels		
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.2 °C Turbidity = 1.6 NTU Black Disc = 3.8m Total Suspended sediment = 2 g/m^3 (1 inorganic; 1 organic)			
WATER FLOW	Flow gauged on 21 March 2002 by Mike Ede = 432 l/s			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Springlands large urban spring-fed stream - NZMS 260 P28 881662			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill, Ally Jerram & Peter Davidson on 21 March 2002. Spotlight fish survey carried out that night. Access through old fruit orchard.			

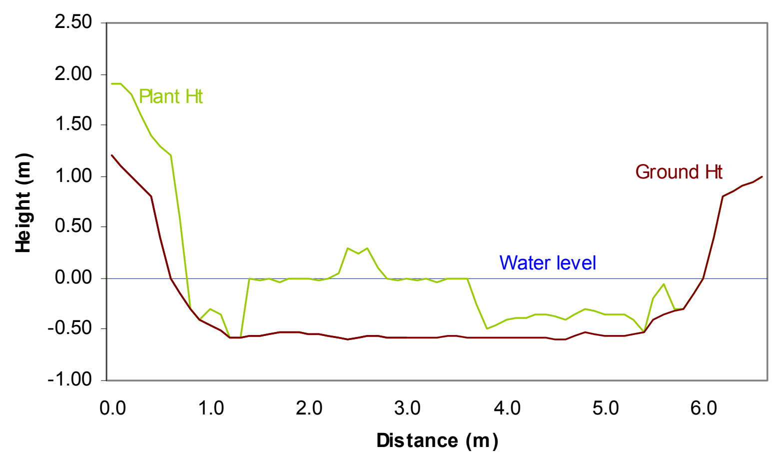
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-GOOD**

ECOLOGICAL ASSESSMENT - SITE 16 **21 March 2002**

DOCTORS

Looking downstream from Battys Road

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified rural watercourse with good flow and clear water	Surrounding land use and ownership	Could be utilised more with fish habitat enhancement due to proximity to Taylor River	
FISH	Inanga, Shortfin eels, Longfin eels, Common bully	Continual modification of habitat	Provision of stable habitat through enhancement	
AQUATIC PLANT SPECIES	Starwort, *Nitella*, Willow weed, Duckweed, *Ranunculus*, Watercress Algae (*Vaucheria*)	Control	Modify control methods to suit enhancement of habitat	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 69 SQMCI = 4.58 EPT taxa = 15 % Species Richness = 13 Dominant taxon = amphipods Crustacea = amphipods & seed shrimp	Aquatic plant control Runoff from surrounding landuse, high turbidity	Increased species richness	Good quality community but species richness poor
RIPARIAN & BANK PLANT SPECIES	TL bank fenced with rough pasture bankside vegetation, but no fencing on TR and unstable banks	Land use	Stream shading and habitat enhancement programme worth considering	
INSTREAM MICROBIOLOGICAL	*E. coli* = 210 cfu/100 ml	Agricultural runoff Stock access	Fencing and riparian planting	Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 212µS/cm pH = 6.6 Dissolved Oxygen = 9.9mg/l (103% saturation)	High groundwater nitrate levels		

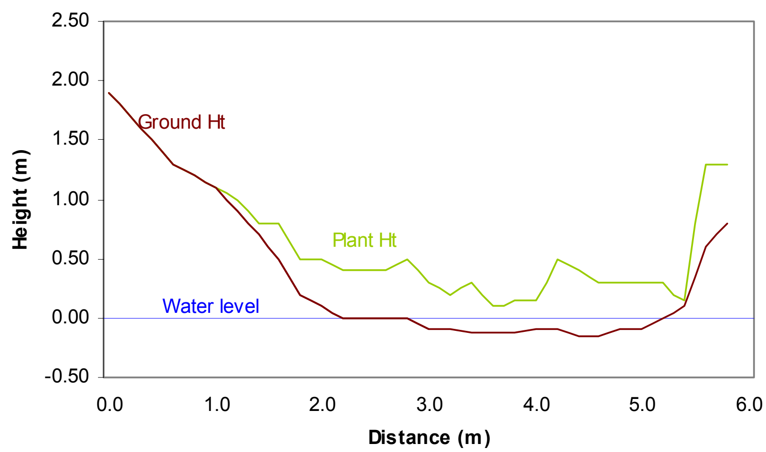
	Total Nitrogen = 3.4g/m^3 Ammonium-N = 0.017g/m^3 Nitrate-N = 2.0g/m^3 Total Phosphorus = 0.074g/m^3 Dissolved P = 0.048g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 17.3 °C Turbidity = 6.8 NTU Black Disc = 1.2 m Total Suspended sediment = 4 g/m^3 (3 inorganic; 1 organic)			
WATER FLOW	Flow gauged on 22 March 2002 by Mike Ede = 333 l/s Also gauged on 27 July 1994 (3919 l/s), 23 January 1997 (214 l/s), 27 March 2001 (0 l/s), 7 June 2001 (55 l/s), 3 September 2001 (233 l/s), and 5 September 2001 (250 l/s).			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Rural Taylor/Opawa River spring-fed tributary - NZMS 260 P28 879649			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 21 March 2002. Access from Battys road.			

OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 17 21 March 2002

YELVERTON

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Small rural stream prone to drying up	Flow	With regular flow would offer good habitat	
FISH	Shortfin eels	Flow	Diversity of habitat features and close to Taylor River offer potentially good fish habitat	Whitebait reported running up this stream when it flowed more regularly 16 years prior
AQUATIC PLANT SPECIES	Watercress, Willow weed, Monkey musk, *Glyceria*			
MACROINVERTEBRATES & CRUSTACEA	MCI index = 77 SQMCI = 2.26 EPT taxa = 42 % Species Richness = 26 Dominant taxon = worms Crustacea = amphipods & seed shrimp	Lack of flow and low dissolved oxygen Further flow reductions will reduce habitat for macroinvertebrates, and may lower species richness and % EPT taxa	Increased flow and dissolved oxygen levels may allow more sensitive crustacean taxa to dominate	High species richness and % EPT taxa, but community dominated by tolerant taxa
RIPARIAN & BANK PLANT SPECIES	Mix of fenced and unfenced with pasture and some shrubs	Surrounding land use	Riparian shade planting will control aquatic plant growth and provide some bank stability	
INSTREAM MICROBIOLOGICAL	*E. coli* = 60 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 161µS/cm pH = 6.4 Dissolved Oxygen = 4.0mg/l (43% saturation) Total Nitrogen = 1.3g/m^3	Lack of flow		

	Ammonium-N = 0.061g/m^3 Nitrate-N = 0.58g/m^3 Total Phosphorus = 0.044g/m^3 Dissolved P = 0.028g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 18.4 °C Turbidity = 1.4 NTU Total Suspended sediment = 4 g/m^3 (2 inorganic; 2 organic)	Little flow Weak connection with the aquifer		
WATER FLOW	Flow gauged on 3 September 2001 = 1 l/s			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Small rural Taylor/Opawa River spring-fed tributary - NZMS 260 P28 871652			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 21 March 2002. Access from David Street.			

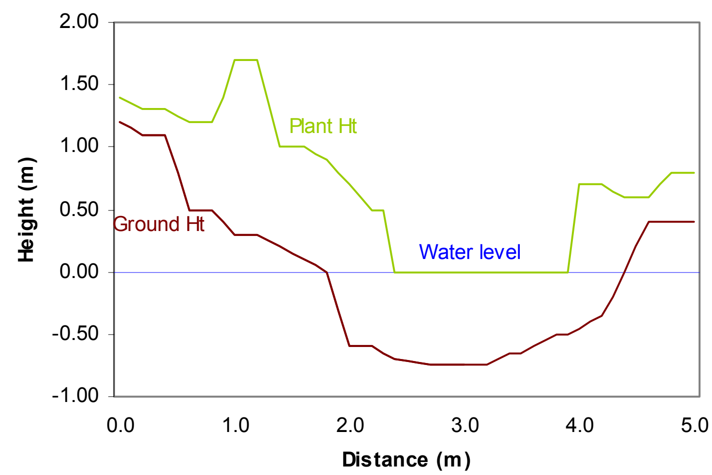
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 18 **21 March 2002**

RIVERLANDS INDUSTRIAL

Looking downstream from SH1

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Highly modified and stagnant rural drain	Lack of flow and elevation		
FISH	No fish	Lack of flow and access difficulty	Major water quality change needed	
AQUATIC PLANT SPECIES	Duckweed Algae (*Spirogyra*) present			
MACROINVERTEBRATES & CRUSTACEA	MCI index = 74 SQMCI index = 2.23 EPT taxa = 7 % Species Richness = 14 Dominant taxa = worms, snails (*Physa*) Crustacea = seed shrimp	Lack of flow, poor water quality and low dissolved oxygen	Quality of the macroinvertebrate community would improve with increased flow, but any change is likely to be limited by poor water quality	
RIPARIAN & BANK PLANT SPECIES	Fenced both sides and good bankside growth of rough pasture and sedges. Some shading provided by hedge of pines on north side		Further riparian planting potential in fenced off sections	
INSTREAM MICROBIOLOGICAL	*E. coli* = 20 000 cfu/100 ml Extremely high	Serious industrial contaminant input	Contaminant control	A long way above guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 496µS/cm pH = 6.3 Dissolved Oxygen = 0.37mg/l (4% saturation) Total Nitrogen = 3.6g/m^3	Serious industrial contaminant input High groundwater nitrate	Contaminant control Increased tidal flushing??	

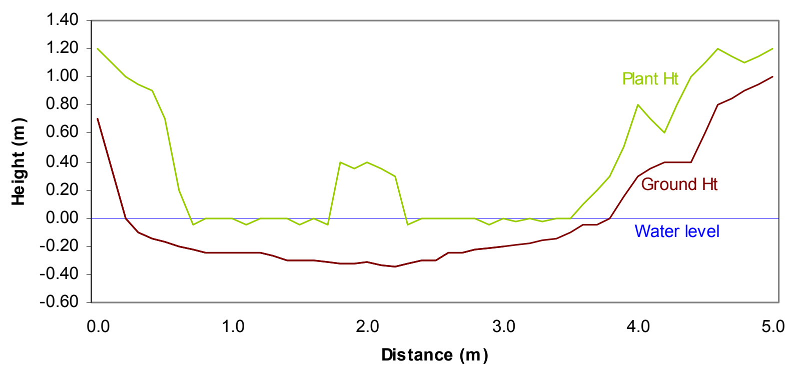
	Ammonium-N = 0.51g/m^3 Nitrate-N = 0.01g/m^3 Total Phosphorus = 1.9g/m^3 Dissolved P = 1.3g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 19.5 °C Turbidity = 82.4 NTU Black Disc = 0.1m Total Suspended sediment = 54 g/m^3 (42 inorganic; 12 organic)	Serious industrial contaminant input Weak connection with the aquifer	Contaminant control	
WATER FLOW	Not gauged			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Impacted Riverlands drain - NZMS 260 P28 952631			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 21 March 2002. Access from SH1.			

OVERALL ECOLOGICAL ASSESSMENT	**VERY POOR**

ECOLOGICAL ASSESSMENT - SITE 19 21 March 2002

RIVERLANDS CO-OP

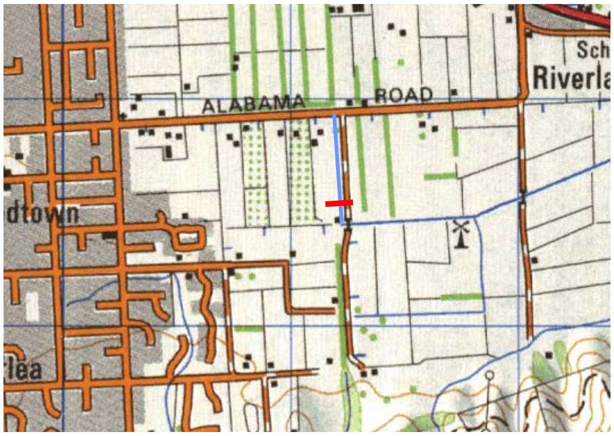
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Highly modified urban waterway	Featureless and subject to machine clearing	Habitat enhancement opportunities	
FISH	Shortfin eels Common bully Inanga	As above	As above and through disturbance reduction with less control activities	
AQUATIC PLANT SPECIES	*Lagarosiphon, Potamogeton*, Watercress	Regular control	Shading with riparian planting to reduce need for regular control	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 79 SQMCI index = 3.13 EPT taxa = 15 % Species Richness = 20 Dominant taxa = *Oxyethira* (cased-caddis), snails (*Physa* & *Potamopyrgus*) Crustacea = amphipods & seed shrimp	Regular control of aquatic plants High turbidity, poor water quality	Improved water quality / clarity would allow more sensitive taxa to colonise.	
RIPARIAN & BANK PLANT SPECIES	LB fenced and vineyards, RB grazed to stream bank	Surrounding land use	Fencing and planting for shade and habitat	
INSTREAM MICROBIOLOGICAL	*E. coli* = 480 cfu/100 ml	Urban runoff	Contaminant control	Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 250µS/cm pH = 6.9 Dissolved Oxygen = 9.0mg/l (102% saturation)	High groundwater nitrate Urban runoff		

	Total Nitrogen = 5.3g/m^3 Ammonium-N = 0.077g/m^3 Nitrate-N = 3.3g/m^3 Total Phosphorus = 0.099g/m^3 Dissolved P = 0.058g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 21.3 °C Turbidity = 21 NTU Black Disc = 0.35m Total Suspended sediment = 16 g/m^3 (14 inorganic; 2 organic)	Weak connection with the aquifer Large inorganic sediment input	Minimise sediment input and bed disturbance	
WATER FLOW	Not gauged			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Riverlands urban waterway - NZMS 260 P28 911635			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 21 March 2002. Spotlight fish survey carried out that night. Access from new lifestyle development road.			

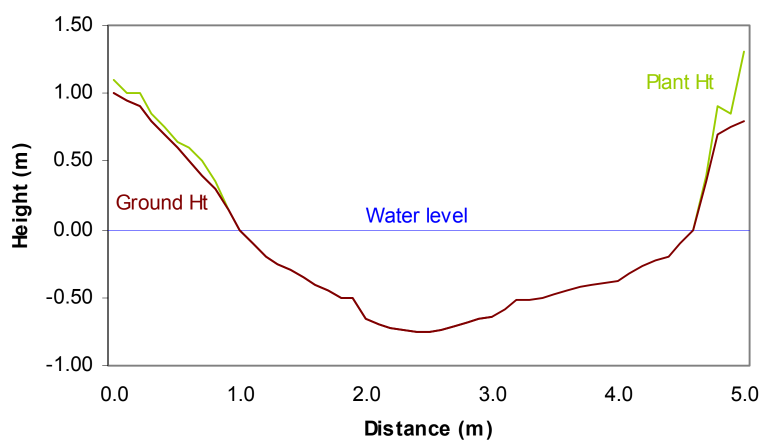
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-POOR**

ECOLOGICAL ASSESSMENT - SITE 20 21 March 2002

TOWN BRANCH



DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified urban watercourse	Surrounding land use		
FISH	Inanga Shortfin eels	Featureless and no habitat diversity	Habitat enhancement opportunities	
AQUATIC PLANT SPECIES	Recently cleared and only remnants of Willow weed, Watercress, *Potamogeton* Algae (*Vaucheria*; *Oedogonium*) present	Regular control		
MACROINVERTEBRATES & CRUSTACEA	MCI index = 77 SQMCI index = 3.44 EPT taxa = 10 % Species Richness = 20 Dominant taxon = snails (*Potamopyrgus*) Crustacea = amphipods & seed shrimp	Regular control of aquatic plants and lack of overhanging streamside vegetation High turbidity, poor water quality	Growth of overhanging streamside vegetation and aquatic plants would provide habitat for macroinvertebrates Improved water quality / clarity would allow more sensitive taxa to colonise.	
RIPARIAN & BANK PLANT SPECIES	Mown road verge on TL bank and fenced TR with rank pasture	Road verge and land ownership	Bankside shrub species for shade and cover needed	
INSTREAM MICROBIOLOGICAL	*E. coli* = 980 cfu/100 ml	Urban runoff		Well above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 217µS/cm pH = 7.1 Dissolved Oxygen = 9.6mg/l (106% saturation)	High groundwater nitrate Urban runoff		

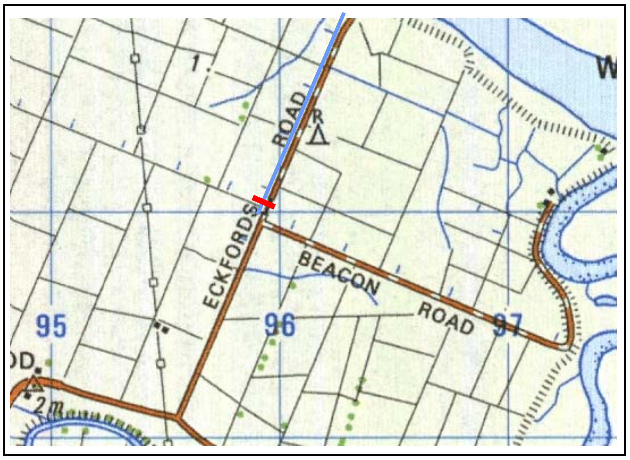
	Total Nitrogen = 5.5g/m^3 Ammonium-N = 0.051g/m^3 Nitrate-N = 3.7g/m^3 Total Phosphorus = 0.095g/m^3 Dissolved P = 0.072g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 20.4 °C Turbidity = 6.2 NTU Black Disc = 1.4m Total Suspended sediment = 5 g/m^3 (4 inorganic; 1 organic)	Weak connection with the aquifer		
WATER FLOW	Not gauged			
CROSS-SECTION & SUBSTRATE				

LOCATION & ZONE	Riverlands urban waterway - NZMS 260 P28 912635
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, & Rowan Strickland on 21 March 2002. Spotlight fish survey carried out that night. Access from new lifestyle development road.

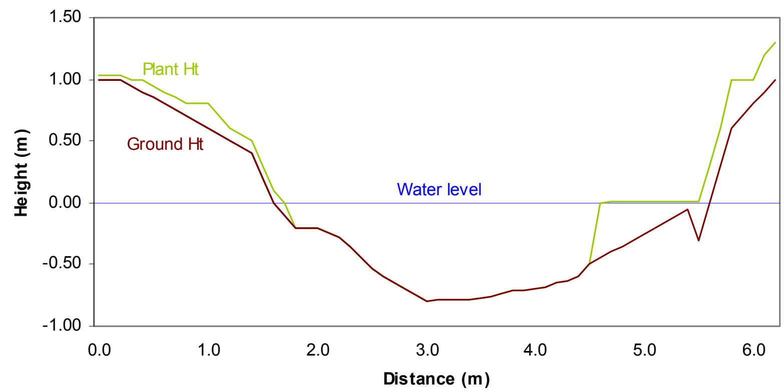
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM-POOR**

ECOLOGICAL ASSESSMENT - SITE 21 22 March 2002

JEFFREYS



DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified rural watercourse	Semi estuarine and flow restricted by control gates Low elevation		Possibly too low in elevation for significant improvement
FISH	Shortfin eels	Access and water quality	Gate operation to allow more regular flushing and access	
AQUATIC PLANT SPECIES	*Ruppia* Algae (*Enteromorpha* spp.; *Lyngbya*; *Cladophora*) common	Estuarine		
MACROINVERTEBRATES & CRUSTACEA	Not sampled Estuarine fauna	Estuarine, low dissolved oxygen and lack of flushing		
RIPARIAN & BANK PLANT SPECIES	Rank pasture within fenced TL bank and TR road verge	Road verge	North bank (TL) needs shrubs for shade and cover	
INSTREAM MICROBIOLOGICAL	*E. coli* = 25 cfu/100 ml			
INSTREAM CHEMICAL PROPERTIES	Conductivity = 4170µS/cm pH = 7.7 Dissolved Oxygen = 2.5mg/l (31% saturation) Total Nitrogen = 1.0g/m^3 Ammonium-N = 0.009g/m^3 Nitrate-N = <0.002g/m^3 Total Phosphorus = 0.81g/m^3 Dissolved P = 0.75g/m^3	Little flow	More water movement through improved tidal flushing	Maybe too low lying to allow tidal fluctuations

INSTREAM PHYSICAL PROPERTIES	Temperature = 17.6 °C Turbidity = 6.0 NTU Black Disc = 1.1m Total Suspended sediment = 40 g/m^3 (31 inorganic; 9 organic)	Weak connection with the aquifer		
WATER FLOW	Not gauged – water level controlled by tidal fluctuation. Flushing restricted by floodgates.			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Lower Wairau Plain – strongly influenced by tides - NZMS 260 P28 959660			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe & Rowan Strickland on 22 March 2002. Spotlight fish survey carried out the previous night. Access from Eckfords road.			

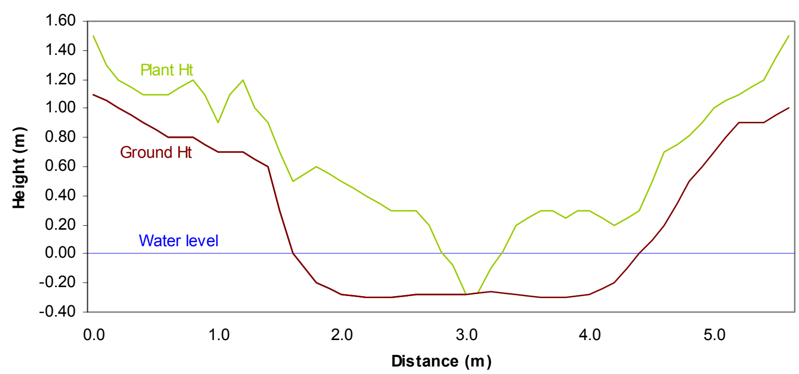
OVERALL ECOLOGICAL ASSESSMENT	**POOR**

ECOLOGICAL ASSESSMENT - SITE 22 22 March 2002

FAIRHALL

Looking downstream from Bells Road

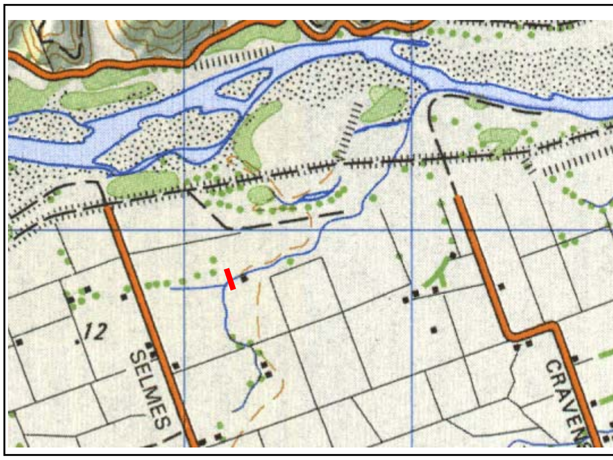
DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Modified rural watercourse	Surrounding land use		
FISH	Inanga Shortfin eels	Good fish habitat while sufficient aquatic plants present	Habitat would improve with less disturbance due to aquatic plants control	
AQUATIC PLANT SPECIES	Watercress, Willow weed, *Glyceria* Algae (*Eunotia*) present	Control	Shrubs on north side for shade will reduce the frequency for control	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 69 SQMCI = 3.45 EPT taxa = 7 % Species Richness = 15 Dominant taxa = amphipods, seed shrimp Crustacea = koura, amphipods & seed shrimp	Enriched runoff may promote occurrence of more tolerant taxa		
RIPARIAN & BANK PLANT SPECIES	Fenced and mixed native shrubs planted on TR and electric fence on TL with rank pasture	Cattle race on TL	Low shrubs similar to TR need planting on North side (TL) Maintain rank pasture for filtering nutrient input from race	
INSTREAM MICROBIOLOGICAL	*E. coli* = 50 cfu/100 ml			Effective stock exclusion
INSTREAM CHEMICAL PROPERTIES	Conductivity = 262µS/cm pH = 6.7 Dissolved Oxygen = 7.9mg/l (78% saturation)	High groundwater nitrate Agricultural runoff	Maintain rank pasture for filtering nutrient input from race	

	Total Nitrogen = 3.4g/m^3 Ammonium-N = 0.019g/m^3 Nitrate-N = 2.3g/m^3 Total Phosphorus = 0.045g/m^3 Dissolved P = 0.033g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 14.5 °C Turbidity = 2.4 NTU Black Disc = 3.1m Total Suspended sediment = 3 g/m^3 (2 inorganic; 1 organic)			
WATER FLOW	Flow gauged on 23 January 1997 (52 l/s) and 3 September 2001 (12 l/s)			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Rural Taylor/Opawa River spring-fed tributary - NZMS 260 P28 857648			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 22 March 2002. Access from Bells road.			

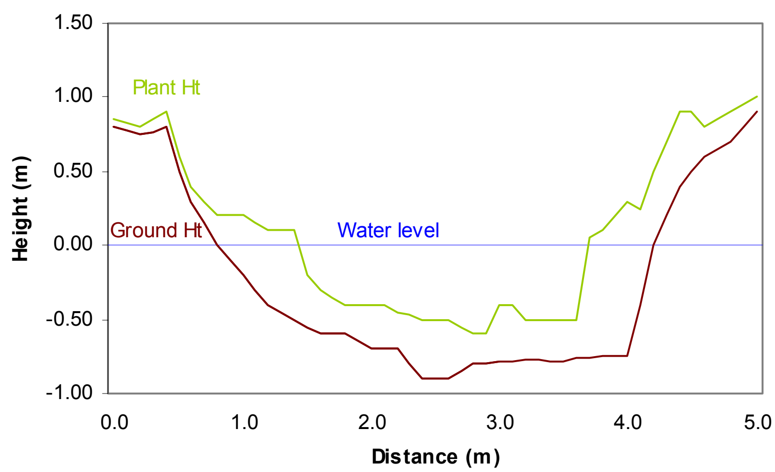
OVERALL ECOLOGICAL ASSESSMENT	**MEDIUM**

ECOLOGICAL ASSESSMENT - SITE 23 — 22 March 2002

CRAVENS



DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Good flow in modified rural setting	Land use	Habitat enhancement	
FISH	Brown trout, Inanga, Longfin eel, Shortfin eel	Land use and threat to instream habitat via control	Riparian management and habitat enhancement	Potential for greater use by fish with habitat enhancement, given close proximity to Wairau
AQUATIC PLANT SPECIES	Watercress, *Potamogeton, Nitella* Algae (*Palmella mucosa*) present	Control	Stream shading may reduce the need for frequent control and habitat disturbance	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 78 SQMCI = 4.17 EPT taxa = 20 % Species Richness = 25 Dominant taxa = amphipods, snails (*Potamopyrgus*) Crustacea = koura, amphipods & seed shrimp present			
RIPARIAN & BANK PLANT SPECIES	Unfenced on both sides with grazed pasture to stream banks	Land use	Habitat improvement potential and stream shading with fencing and planting	
INSTREAM MICROBIOLOGICAL	*E. coli* = 180 cfu/100 ml	Stock access	Fencing	Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 105µS/cm pH = 6.7 Dissolved Oxygen = 6.3mg/l (62% saturation) Total Nitrogen = 0.52g/m^3			

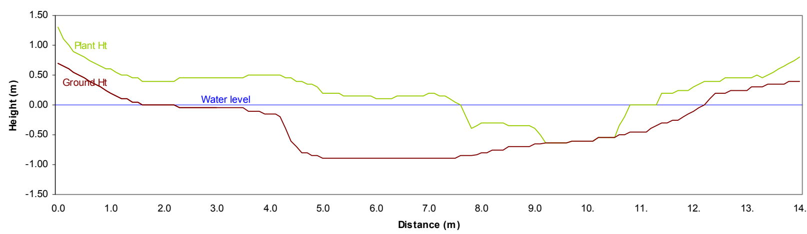
	Ammonium-N = 0.016g/m^3 Nitrate-N = 0.35g/m^3 Total Phosphorus = 0.019g/m^3 Dissolved P = 0.017g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 14.6 °C Turbidity = 1.1 NTU Black Disc = 6.4m Total Suspended sediment = 3 g/m^3 (3 inorganic; 0 organic)			
WATER FLOW	Not gauged – large spring flow - NZMS 260 P28 872728			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Large rural spring-fed stream – Spring Creek zone			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Anna Crowe, Rowan Strickland, Peter Hamill & Ally Jerram on 22 March 2002. Spotlight fish survey carried out the previous night in the lower reaches of Cravens Creek. Access through farm off Selmes road.			

OVERALL ECOLOGICAL ASSESSMENT	**GOOD**

ECOLOGICAL ASSESSMENT - SITE 24 22 March 2002

HALLS

DESCRIPTION	EXISTING	LIMITATIONS	POTENTIAL	COMMENTS
GENERAL	Rural stream with less modified course than others	Subject to runoff from dairy farm activities	Management of runoff and better riparian management	
FISH	Longfin eel, Shortfin eel, Inanga, Common bully, Black flounder, Brown trout		Habitat enhancement potential	
AQUATIC PLANT SPECIES	*Egeria*, *Lagarosiphon*, Watercress, Willow weed		Possible control of nuisance species with stream shading	
MACROINVERTEBRATES & CRUSTACEA	MCI index = 78 SQMCI = 4.04 EPT taxa = 18 % Species Richness = 17 Dominant taxon = snails (*Potamopyrgus*) Crustacea = koura, shrimp, amphipods & seed shrimp	Enriched runoff may promote colonisation by more tolerant taxa		
RIPARIAN & BANK PLANT SPECIES	Fenced on both sides with riparian wetland on TR and tall alders shading TL		Further shading possible with TR bank planting	
INSTREAM MICROBIOLOGICAL	*E. coli* = 680 cfu/100 ml	Stock crossing Agricultural runoff	Bridge stock crossing Restrict stock access	Above contact guidelines
INSTREAM CHEMICAL PROPERTIES	Conductivity = 95µS/cm pH = 6.6 Dissolved Oxygen = 5.8mg/l (59% saturation)			

	Total Nitrogen = 0.69g/m^3 Ammonium-N = 0.034g/m^3 Nitrate-N = 0.34g/m^3 Total Phosphorus = 0.052g/m^3 Dissolved P = 0.033g/m^3			
INSTREAM PHYSICAL PROPERTIES	Temperature = 15.7 °C Turbidity = 1.9 NTU Black Disc = 3.6m Total Suspended sediment = 1.8 g/m^3 (0.8 inorganic; 1 organic)			
WATER FLOW	Flow gauged on 19 July 1991 = 242 l/s			
CROSS-SECTION & SUBSTRATE				
LOCATION & ZONE	Large rural spring-fed stream – Spring Creek zone - NZMS 260 P28 899732			
SITE VISIT DETAILS & PERSONNEL	Main survey carried out by Roger Young, Rowan Strickland, Peter Hamill & Ally Jerram on 22 March 2002. Access through Hall's farm off Hillocks road.			

OVERALL ECOLOGICAL ASSESSMENT	**GOOD**

Appendix 2

Relative abundance of macroinvertebrates

Site no:		1	2	3	4	5	6
Site name:	Taxon	Pipi Nth	Pukaka	Roberts	Sadds	Drain N	Drain Q
Date:	score	3/18/02	3/18/02	3/18/02	3/19/02	3/19/02	3/19/02
Mayflies							
Austroclima jollyae	9	-	-	-	-	-	-
Austroclima sepia	9	-	-	-	-	-	-
Zephlebia versicolor	7	-	-	-	-	C	-
Stoneflies							
Megaleptoperla sp.	9	-	-	-	-	-	-
Odonata							
Damselflies (Zygoptera)	5	-	-	R	C	-	C
Austrolestes colensonis	6	-	-	R	C	-	C
Xanthocnemis zelandica	5	R	R	C	-	R	C
Water Bugs							
Anisops sp.	5	C	-	R			
Microvelia sp.	5	-	-	-	R	R	R
Sigara sp.	5	-	-	R	-	C	C
Dobsonflies							
Archichauliodes diversus	7	-	-	-	-	R	-
Beetles							
Antiporus sp.	5	-	-	-	-	-	-
Dyticidae	5	-	-	-		-	-
Enochrus sp.	5	-	-	-	R	-	-
Enochrus tritus	5	-	-	-		-	-
Hydrophilidae	5	-	-	-		-	-
Liodessus deflectus	5	-	R	-	R	-	-
Liodessus sp.	5	-	-	-	R	-	-
Rhantis pulverosus	5	-	R	-		-	R
Scirtidae	8	-	-	-	R	-	-
True Flies							
Anthomyiidae	3	-	-	-	-	-	-
Austrosimulium spp.	3	-	-	-	-	-	-
Chironomus sp. A	1	C	-	-	-	-	-
Chironomus zelandicus	1	VA	-	-	-	-	-
Corynoneura sp.	2	-	-	-	-	A	R
Culex sp.	3	C	-	-	-	-	-
Ephydrella sp.	4	-	-	-	-	-	-
Orthocladiinae	2	R	-	-	-	A	A
Paradixa sp.	4	-	-	-	-	-	-
Paralimnophila skusei	6	-	-	-	-	-	R
Polypedilum spp.	3	-	-	-	-	-	-
Sciomyzidae	3	-	-	-	-	-	-
Stratiomyidae	5	-	-	-	R	-	-
Tanypodinae	5	-	-	-	-	C	R
Tanytarsus vespertinus	3	-	-	-	-	C	R
Caddisflies							
Hudsonema alienum	6	-	-	-	-	-	-
Hudsonema amabile	6	-	-	-	-	-	-
Hydrobiosis budgei	5	-	-	-	-	-	-
Hydrobiosis copis	5	-	-	-	-	-	-
Hydrobiosis parumbripennis	5	-	-	-	-	-	-
Hydrobiosis umbripennis	5	-	-	-	-	-	-
Hydrobiosis spp.	5	-	-	-	-	-	-
Oecetis unicolor	6	-	-	-	-	-	-
Olinga feredayi	9	-	-	-	-	R	-
Hydroptilidae	2	-	-	-	-	-	-

Site no:		1	2	3	4	5	6
Site name:	Taxon	Pipi Nth	Pukaka	Roberts	Sadds	Drain N	Drain Q
Date:	score	3/18/02	3/18/02	3/18/02	3/19/02	3/19/02	3/19/02
Oxyethira albiceps	2	-	-	C	-	C	A
Paroxyethira eatoni cmplx	2	-	-	-	-	-	-
Paroxyethira hendersoni	2	-	-	R	-	-	-
Polyplectropus puerilis	8	-	-	-	-	R	C
Psilochorema bidens	8	-	-	-	-	R	-
Psilochorema nemorale	8						
Psilochorema spp.	8	-	-	-	-	R	-
Pycnocentria evecta	7	-	-	-	-	-	-
Pycnocentrodes sp.	5	-	-	-	-	-	-
Triplectides cephalotes	5	-	-	-	-	-	-
Triplectides obsoletus	5	-	-	-	-	-	-
Moths							
Hygraula nitens	4	-	-	-	-	-	-
Crustacea							
Amphipoda	5	-	A	VVA	-	A	C
Ostracoda	3	-	A	-	-	-	VA
Paranephrops planifrons	5	-	-	-	-	-	-
Paranephrops sp.	5	-	-	-	-	-	-
Paratya curvirostris	5	-	-	C	-	-	-
Annelida	1	A	C	R	VA	C	VA
Platyhelminthes	3	R	R	A	A	-	R
Nematoda	3	-	-	-	-	R	-
Hirudinea	3	-	-	-	-	-	R
Acarina	5	-	R	-	-	-	R
Collembola	6	-	-	-	R	-	VA
Mollusca							
Ferrissia sp.	3	-	-	-	-	-	-
Gyraulus sp.	3	-	C	A	A	-	R
Physa sp.	3	A	A	C	A	A	A
Potamopyrgus antipodarum	4	-	A	C	A	VVA	VVA
Sphaeriidae	3	-	-	-	-	R	C
Number of taxa		9	11	14	14	20	24
MCI		58	76	77	91	94	83
SQMCI		1.49	3.61	4.80	2.30	3.90	3.72
% EPT_{taxa}		0.0	0.0	14.3	0.0	30.0	8.3

Site no:		8	9	10	11	12	13
Site name:	Taxon	Marukoko	Grovetwn	Kellys	Waterlea	Fultons	Caseys
Date:	score	3/19/02	3/20/02	3/20/02	3/20/02	3/20/02	3/20/02
Mayflies							
Austroclima jollyae	9	-	-	R	-	-	-
Austroclima sepia	9	-	-	-	-	-	-
Zephlebia versicolor	7	-	-	R	-	-	-
Stoneflies							
Megaleptoperla sp.	9	-	-	-	-	R	R
Odonata							
Damselflies (Zygoptera)	5	C	R	R	R	-	-
Austrolestes colensonis	6	-	-	R	-	-	-
Xanthocnemis zelandica	5	C	-	C	R	-	R
Water Bugs							
Anisops sp.	5	R	-	R	R	-	-
Microvelia sp.	5	-	A	-	R	-	-
Sigara sp.	5	R	-	R	R	-	R
Dobsonflies							
Archichauliodes diversus	7	-	-	-	-	-	-
Beetles							
Antiporus sp.	5	-	-	-	-	-	-
Dyticidae	5	-	R	-	-	-	-
Enochrus sp.	5	-	-	-	-	-	-
Enochrus tritus	5	-	-	-	-	-	-
Hydrophilidae	5	-	-	-	-	-	-
Liodessus deflectus	5	-	-	-	-	-	-
Liodessus sp.	5	-	-	-	-	-	-
Rhantis pulverosus	5	-	-	-	-	-	-
Scirtidae	8	-	-	-	-	-	-
True Flies							
Anthomyiidae	3	-	-	-	-	-	-
Austrosimulium spp.	3	-	R	A	R	R	-
Chironomus sp. A	1	R	-	-	-	-	-
Chironomus zelandicus	1	-	-	-	-	-	-
Corynoneura sp.	2	-	C		R	-	-
Culex sp.	3	-	-	-	-	-	-
Ephydrella sp.	4	-	-	-	-	-	R
Orthocladiinae	2	R	C	A	C	R	R
Paradixa sp.	4	-	R	R	R	-	-
Paralimnophila skusei	6	-	-	-	R	-	-
Polypedilum spp.	3	-	-	-	-	-	R
Sciomyzidae	3	-	-	R	-	-	-
Stratiomyidae	5	-	-	-	-	-	-
Tanypodinae	5	-	-	-	A	R	C
Tanytarsus vespertinus	3	-	R	-	-	-	R
Caddisflies							
Hudsonema alienum	6	-	-	-	-	-	-
Hudsonema amabile	6	-	-	-	-	C	-
Hydrobiosis budgei	5	-	-	-	-	-	-
Hydrobiosis copis	5	-	-	R	-	-	-
Hydrobiosis parumbripennis	5	-	-	-	-	-	-
Hydrobiosis umbripennis	5	-	-	-	-	-	-
Hydrobiosis spp.	5	-	-	R	R	-	-
Oecetis unicolor	6	-	-	-	-	-	-
Olinga feredayi	9	-	-	-	-	-	-
Hydroptilidae	2	R	-	-	-	-	-

Site no:		8	9	10	11	12	13
Site name:	Taxon	Marukoko	Grovetwn	Kellys	Waterlea	Fultons	Caseys
Date:	score	3/19/02	3/20/02	3/20/02	3/20/02	3/20/02	3/20/02
Oxyethira albiceps	2	-	-	C	C	-	-
Paroxyethira eatoni cmplx	2	-	-	-	-	-	-
Paroxyethira hendersoni	2	R	-	R	-	-	-
Polyplectropus puerilis	8	-	-	-	A	-	R
Psilochorema bidens	8	-	R	-	C	R	R
Psilochorema nemorale	8						
Psilochorema spp.	8	-	-	R	R	R	R
Pycnocentria evecta	7	-	-	R	-	-	-
Pycnocentrodes sp.	5	-	-	-	-	-	-
Triplectides cephalotes	5	-	-	-	-	-	-
Triplectides obsoletus	5	-	-	-	-	R	-
Moths							
Hygraula nitens	4	R	-	-	-	-	-
Crustacea							
Amphipoda	5	A	VA	A	A	VA	VVA
Ostracoda	3	-	-	C	VA	A	C
Paranephrops planifrons	5	-	-	-	R	R	
Paranephrops sp.	5	-	-	-	R	-	R
Paratya curvirostris	5	-	R	-	R	-	-
Annelida	1	R	-	R	VA	VA	R
Platyhelminthes	3	-	-	-	-	C	R
Nematoda	3	-	-	-	-	-	-
Hirudinea	3	-	-	-	-	R	-
Acarina	5	-	-	-	-	-	-
Collembola	6	-	C	-	-	R	-
Mollusca							
Ferrissia sp.	3	-	R	C	-	-	C
Gyraulus sp.	3	-	-	A	-	-	A
Physa sp.	3	-	R	A	C	R	VA
Potamopyrgus antipodarum	4	VVA	VA	VA	C	VA	VVA
Sphaeriidae	3	-	-	-	A	C	C
Number of taxa		12	15	24	25	18	21
MCI		68	87	87	88	87	85
SQMCI		4.04	4.46	3.66	3.08	3.40	4.33
% EPT_{taxa}		16.7	6.7	33.3	20.0	27.8	19.0

Site no:		14	15	16	17	18	19
Site name:	Taxon	Woolley	Murphys	Doctors	Yelvertn	Riv Ind	Riv Co-op
Date:	score	3/21/02	3/21/02	3/21/02	3/21/02	3/21/02	3/21/02
Mayflies							
Austroclima jollyae	9	-	-	-	-	-	-
Austroclima sepia	9	-	-	-	-	-	-
Zephlebia versicolor	7	-	-	-	-	-	-
Stoneflies							
Megaleptoperla sp.	9	-	-	-	-	-	-
Odonata							
Damselflies (Zygoptera)	5	C	-	C	R	-	-
Austrolestes colensonis	6	-	-	-	-	R	R
Xanthocnemis zelandica	5	C	-	R	R	C	A
Water Bugs							
Anisops sp.	5	-	-	-	-	-	-
Microvelia sp.	5	C	-	-	-	-	R
Sigara sp.	5	R	-	C	VA	-	A
Dobsonflies							
Archichauliodes diversus	7	-	-	-	-	-	-
Beetles							
Antiporus sp.	5	-	-	-	R	R	-
Dyticidae	5	-	-	-	-	-	-
Enochrus sp.	5	-	-	-	-	-	-
Enochrus tritus	5	R	-	-	-	R	R
Hydrophilidae	5	-	-	-	-	R	-
Liodessus deflectus	5	-	-	-	-	R	-
Liodessus sp.	5	-	-	-	-	-	-
Rhantis pulverosus	5	-	R	-	-	-	R
Scirtidae	8	-	-	-	-	-	-
True Flies							
Anthomyiidae	3	-	-	-	R	-	-
Austrosimulium spp.	3	-	-	-	C	-	-
Chironomus sp. A	1	-	-	R	A	-	-
Chironomus zelandicus	1	VA	-	-	R	A	-
Corynoneura sp.	2	-	-	-	-	-	-
Culex sp.	3	-	-	-	-	R	C
Ephydrella sp.	4	-	-	-	-	-	-
Orthocladiinae	2	R	VA	R	A	C	A
Paradixa sp.	4	-	-	-	-	-	-
Paralimnophila skusei	6	-	-	-	-	-	-
Polypedilum spp.	3	-	-	-	-	-	-
Sciomyzidae	3	-	-	-	-	-	-
Stratiomyidae	5	C	-	-	-	-	R
Tanypodinae	5	-	R	-	-	-	-
Tanytarsus vespertinus	3	-	-	-	-	-	-
Caddisflies							
Hudsonema alienum	6	-	-	-	R	-	R
Hudsonema amabile	6	-	-	-	R	-	-
Hydrobiosis budgei	5	-	-	-	-	-	-
Hydrobiosis copis	5	-	-	-	R	-	-
Hydrobiosis parumbripennis	5	-	-	-	R	-	-
Hydrobiosis umbripennis	5	-	-	-	C	-	-
Hydrobiosis spp.	5	-	-	-	R	-	-
Oecetis unicolor	6	-	-	R	-	-	-
Olinga feredayi	9	-	-	-	-	-	-
Hydroptilidae	2	-	-	-	-	-	-

Site no:		14	15	16	17	18	19
Site name:	Taxon	Woolley	Murphys	Doctors	Yelvertn	Riv Ind	Riv Co-op
Date:	score	3/21/02	3/21/02	3/21/02	3/21/02	3/21/02	3/21/02
Oxyethira albiceps	2	-	A	C	VA	-	VVA
Paroxyethira eatoni cmplx	2	-	-	-	-	-	R
Paroxyethira hendersoni	2	-	-	-	A	-	-
Polyplectropus puerilis	8	-	-	-	-	-	-
Psilochorema bidens	8	-	-	-	R	-	-
Psilochorema nemorale	8						
Psilochorema spp.	8	-	-	-	-	-	-
Pycnocentria evecta	7	-	-	-	-	-	-
Pycnocentrodes sp.	5	-	-	-	R	-	-
Triplectides cephalotes	5	-	-	-	R	R	-
Triplectides obsoletus	5	-	R	-	-	-	-
Moths							
Hygraula nitens	4	R	-	-	-	-	-
Crustacea							
Amphipoda	5	C	C	VVA	VA	-	VA
Ostracoda	3	A	C	A	VA	C	A
Paranephrops planifrons	5	-	-	-	-	-	-
Paranephrops sp.	5	-	-	-	-	-	-
Paratya curvirostris	5	-	-	-	-	-	-
Annelida	1	VA	VVA	A	VVA	VA	A
Platyhelminthes	3	A	-	-	-	-	-
Nematoda	3	-	-	-	-	-	-
Hirudinea	3	C	R	-	-	-	-
Acarina	5	-	-	-	-	-	-
Collembola	6	-	-	-	-	-	R
Mollusca							
Ferrissia sp.	3	-	-	-	-	-	-
Gyraulus sp.	3	-	R	R	R	-	VA
Physa sp.	3	C	R	A	A	VA	VVA
Potamopyrgus antipodarum	4	R	VA	VA	R	A	VVA
Sphaeriidae	3	-	-	-	-	-	-
Number of taxa		16	12	13	26	14	19
MCI		74	68	69	77	74	79
SQMCI		1.77	1.64	4.58	2.26	2.23	3.13
% EPT_{taxa}		0.0	16.7	15.4	42.3	7.1	15.8

Site no:		20	22	23	24	SPC4	SPC3
Site name:	Taxon	Twn Brn	Fairhall	Cravens	Halls	Tennis	O'Dwyers
Date:	score	3/21/02	3/22/02	3/22/02	3/22/02	20/10/99	20/10/99
Mayflies							
Austroclima jollyae	9	-	-	-	-	-	-
Austroclima sepia	9	-	-	-	-	R	C
Zephlebia versicolor	7	-	-	-	-	R	A
Stoneflies							
Megaleptoperla sp.	9	-	-	-	-	-	-
Odonata							
Damselflies (Zygoptera)	5	C	-	R	C	-	-
Austrolestes colensonis	6	R	-	R	R	-	-
Xanthocnemis zelandica	5	A	-	C	A	C	-
Water Bugs							
Anisops sp.	5	-	-	-	-	-	-
Microvelia sp.	5	R	-	R	-	-	R
Sigara sp.	5	A	-	A	C	C	C
Dobsonflies							
Archichauliodes diversus	7	-	-	-	-	-	-
Beetles							
Antiporus sp.	5	-	-	-	-	-	-
Dyticidae	5	-	-	-	-	-	-
Enochrus sp.	5	-	-	-	-	-	-
Enochrus tritus	5	-	-	-	-	-	-
Hydrophilidae	5	-	-	-	-	-	-
Liodessus deflectus	5	-	-	-	-	-	-
Liodessus sp.	5	-	R	-	-	-	-
Rhantis pulverosus	5	R	-	-	-	-	-
Scirtidae	8	-	-	-	-	-	-
True Flies							
Anthomyiidae	3	-	R	-	-	-	-
Austrosimulium spp.	3	-	A	-	-	-	A
Chironomus sp. A	1	C	-	R	-	-	-
Chironomus zelandicus	1	R	-	R	R	-	-
Corynoneura sp.	2	-	R	-	-	-	-
Culex sp.	3	-	-	-	-	-	-
Ephydrella sp.	4	-	-	-	-	-	-
Orthocladiinae	2	A	A	C	R	A	A
Paradixa sp.	4	-	-	-	-	-	-
Paralimnophila skusei	6	-	-	-	-	-	-
Polypedilum spp.	3	-	-	-	-	-	-
Sciomyzidae	3	-	-	R	-	-	-
Stratiomyidae	5	-	-	-	-	-	-
Tanypodinae	5	R	C	R	R	R	R
Tanytarsus vespertinus	3	-	R	-	-	-	-
Caddisflies							
Hudsonema alienum	6	-	-	-	-	-	R
Hudsonema amabile	6	-	-	-	-	-	C
Hydrobiosis budgei	5	-	-	-	-	-	-
Hydrobiosis copis	5	-	-	-	-	-	-
Hydrobiosis parumbripennis	5	-	-	-	-	-	-
Hydrobiosis umbripennis	5	-	-	-	-	-	-
Hydrobiosis spp.	5	-	-	R	-	R	-
Oecetis unicolor	6	-	-	-	-	-	-
Olinga feredayi	9	-	-	-	-	-	-
Hydroptilidae	2	-	-	-	-	-	-

Site no:		20	22	23	24	SPC4	SPC3
Site name:	Taxon	Twn Brn	Fairhall	Cravens	Halls	Tennis	O'Dwyers
Date:	score	3/21/02	3/22/02	3/22/02	3/22/02	20/10/99	20/10/99
Oxyethira albiceps	2	R	A	R	R	A	C
Paroxyethira eatoni cmplx	2	-	-	-	-	-	-
Paroxyethira hendersoni	2	-	-	R	-	-	-
Polyplectropus puerilis	8	-	-	C	R	R	C
Psilochorema bidens	8	-	-	R	-	-	-
Psilochorema nemorale	8					R	R
Psilochorema spp.	8	-	-	-	-	-	-
Pycnocentria evecta	7	-	-	-	-	C	VA
Pycnocentrodes sp.	5	-	-	-	-	-	-
Triplectides cephalotes	5	C	-	-	R	-	-
Triplectides obsoletus	5	-	-	-	-	-	-
Moths							
Hygraula nitens	4	-	-	-	-	-	-
Crustacea							
Amphipoda	5	A	VA	VVA	VA	VVA	VVA
Ostracoda	3	VA	VA	A	C	C	R
Paranephrops planifrons	5	-	-	-	-	-	-
Paranephrops sp.	5	-	-	-	-	-	-
Paratya curvirostris	5	-	-	-	-	-	-
Annelida	1	VA	A	A	A	A	C
Platyhelminthes	3	-	R	C	A	-	-
Nematoda	3	-	-	-	-	-	-
Hirudinea	3	-	-	R	-	-	-
Acarina	5	R	-	-	-	-	-
Collembola	6	-	R	-	-	-	-
Mollusca							
Ferrissia sp.	3	-	-	R	-	R	-
Gyraulus sp.	3	VA	-	VA	-	A	-
Physa sp.	3	A	C	VA	A	A	R
Potamopyrgus antipodarum	4	VVA	R	VVA	VVA	VVA	C
Sphaeriidae	3	A	-	A	R	A	-
Number of taxa		20	15	25	17	19	17
MCI		77	69	78	78	93	98
SQMCI		3.44	3.45	4.17	4.04	4.29	5.2
% EPT_{taxa}		10.0	6.7	20.0	17.6	36.8	47.1

Site no:		SPC10	SPC9	SPC2	SPC8	SPC7	SPC6
Site name:	Taxon	Hollis	Ganes	Rapaura	Dentons	Motor	Roses
Date:	score	20/10/99	20/10/99	20/10/99	20/10/99	20/10/99	20/10/99
Mayflies							
Austroclima jollyae	9	-	-	-	-	-	-
Austroclima sepia	9	R	-	R	-	-	-
Zephlebia versicolor	7	R	-	R	C	C	R
Stoneflies							
Megaleptoperla sp.	9	-	-	-	-	-	-
Odonata							
Damselflies (Zygoptera)	5	-	-	-	-	-	-
Austrolestes colensonis	6	-	-	-	-	-	-
Xanthocnemis zelandica	5	R	R	R	-	-	R
Water Bugs							
Anisops sp.	5	-	-	-	-	-	-
Microvelia sp.	5	-	-	-	-	-	-
Sigara sp.	5	-	-	-	-	-	-
Dobsonflies							
Archichauliodes diversus	7	-	-	-	-	-	-
Beetles							
Antiporus sp.	5	-	-	-	-	-	-
Dyticidae	5	-	-	-	-	-	-
Enochrus sp.	5	-	-	-	-	-	-
Enochrus tritus	5	-	-	-	-	-	-
Hydrophilidae	5	-	-	-	-	-	-
Liodessus deflectus	5	-	-	-	-	-	-
Liodessus sp.	5	-	-	-	-	-	-
Rhantis pulverosus	5	-	-	-	-	-	-
Scirtidae	8	-	-	-	-	-	-
True Flies							
Anthomyiidae	3	-	-	-	-	-	-
Austrosimulium spp.	3	-	R	R	R	A	R
Chironomus sp. A	1	-	-	A	-	-	-
Chironomus zelandicus	1	-	-	-	-	-	-
Corynoneura sp.	2	-	-	-	-	-	-
Culex sp.	3	-	-	-	-	-	-
Ephydrella sp.	4	-	-	-	-	-	-
Orthocladiinae	2	VA	C	A	VVA	A	R
Paradixa sp.	4	-	-	-	-	-	-
Paralimnophila skusei	6	-	R	-	-	-	-
Polypedilum spp.	3	R	-	R	R	R	-
Sciomyzidae	3	-	-	-	-	-	-
Stratiomyidae	5	-	-	-	-	-	-
Tanypodinae	5	R	R	R	-	-	-
Tanytarsus vespertinus	3	-	-	R	-	-	-
Caddisflies							
Hudsonema alienum	6	-	-	-	-	-	-
Hudsonema amabile	6	-	-	-	-	-	-
Hydrobiosis budgei	5	-	-	-	-	R	-
Hydrobiosis copis	5	-	-	-	-	-	-
Hydrobiosis parumbripennis	5	-	-	-	-	-	-
Hydrobiosis umbripennis	5	-	-	-	-	-	-
Hydrobiosis spp.	5	-	-	-	-	R	-
Oecetis unicolor	6	-	-	-	-	-	-
Olinga feredayi	9	-	-	-	-	-	-
Hydroptilidae	2	-	-	-	-	-	-

Site no:		SPC10	SPC9	SPC2	SPC8	SPC7	SPC6
Site name:	Taxon	Hollis	Ganes	Rapaura	Dentons	Motor	Roses
Date:	score	20/10/99	20/10/99	20/10/99	20/10/99	20/10/99	20/10/99
Oxyethira albiceps	2	C	-	-	C	C	R
Paroxyethira eatoni cmplx	2	-	-	-	-	-	-
Paroxyethira hendersoni	2	R	-	R	-	R	-
Polyplectropus puerilis	8	A	-	C	C	R	-
Psilochorema bidens	8	-	-	-	-	-	-
Psilochorema nemorale	8	C	-	-	-	-	-
Psilochorema spp.	8	-	-	-	-	-	-
Pycnocentria evecta	7	VA	-	R	-	C	-
Pycnocentrodes sp.	5	-	-	-	-	-	-
Triplectides cephalotes	5	-	-	-	-	-	-
Triplectides obsoletus	5	-	-	-	-	-	-
Moths							
Hygraula nitens	4	-	-	-	-	-	-
Crustacea							
Amphipoda	5	VVA		VA	VA	VVA	R
Ostracoda	3	A	C	A	C	R	A
Paranephrops planifrons	5	-	-	-	-	-	-
Paranephrops sp.	5	-	-	R	R	-	-
Paratya curvirostris	5	-	-	-	-	-	-
Annelida	1	VA	VVA	VA	VVA	A	VVA
Platyhelminthes	3	-	-	-	-	-	R
Nematoda	3	-	-	-	-	-	-
Hirudinea	3	-	-	-	-	-	-
Acarina	5	-	-	-	-	-	-
Collembola	6	-	-	-	-	-	-
Mollusca							
Ferrissia sp.	3	-	-	-	-	-	R
Gyraulus sp.	3	-	-	-	-	-	-
Physa sp.	3	-	R	R	R	-	-
Potamopyrgus antipodarum	4	A	VVA	-	A	A	VA
Sphaeriidae	3	A	C	-	R	C	VA
Number of taxa		16	10	17	13	14	12
MCI		93	70	85	75	79	68
SQMCI		4.4	2.51	2.94	1.92	4.66	1.77
% EPT_{taxa}		43.8	0.0	29.4	23.1	50.0	16.7

Site no: Site name: Date:	Taxon score	SPC5 Collins 20/10/99	SPC1 Flood 20/10/99
Mayflies			
Austroclima jollyae	9	-	-
Austroclima sepia	9	-	R
Zephlebia versicolor	7	R	C
Stoneflies			
Megaleptoperla sp.	9	-	-
Odonata			
Damselflies (Zygoptera)	5	-	-
Austrolestes colensonis	6	-	-
Xanthocnemis zelandica	5	C	-
Water Bugs			
Anisops sp.	5	-	-
Microvelia sp.	5	C	-
Sigara sp.	5	-	R
Dobsonflies			
Archichauliodes diversus	7	-	-
Beetles			
Antiporus sp.	5	-	-
Dyticidae	5	-	-
Enochrus sp.	5	-	-
Enochrus tritus	5	-	-
Hydrophilidae	5	-	-
Liodessus deflectus	5	-	-
Liodessus sp.	5	-	-
Rhantis pulverosus	5	-	-
Scirtidae	8	-	-
True Flies			
Anthomyiidae	3	-	-
Austrosimulium spp.	3	R	A
Chironomus sp. A	1	R	-
Chironomus zelandicus	1	-	-
Corynoneura sp.	2	-	-
Culex sp.	3	-	-
Ephydrella sp.	4	-	-
Orthocladiinae	2	A	A
Paradixa sp.	4	-	-
Paralimnophila skusei	6	-	-
Polypedilum spp.	3	-	-
Sciomyzidae	3	-	-
Stratiomyidae	5	-	-
Tanypodinae	5	-	-
Tanytarsus vespertinus	3	-	-
Caddisflies			
Hudsonema alienum	6	-	-
Hudsonema amabile	6	-	-
Hydrobiosis budgei	5	R	-
Hydrobiosis copis	5	-	-
Hydrobiosis parumbripennis	5	-	-
Hydrobiosis umbripennis	5	-	-
Hydrobiosis spp.	5	-	R
Oecetis unicolor	6	-	-
Olinga feredayi	9	-	-
Hydroptilidae	2	-	-

Site no:		SPC5	SPC1
Site name:	Taxon	Collins	Flood
Date:	score	20/10/99	20/10/99
Oxyethira albiceps	2	C	A
Paroxyethira eatoni cmplx	2	-	-
Paroxyethira hendersoni	2	R	-
Polyplectropus puerilis	8	C	-
Psilochorema bidens	8	-	-
Psilochorema nemorale	8	-	R
Psilochorema spp.	8	-	-
Pycnocentria evecta	7	C	A
Pycnocentrodes sp.	5	-	-
Triplectides cephalotes	5	-	-
Triplectides obsoletus	5	-	-
Moths			
Hygraula nitens	4	-	-
Crustacea			
Amphipoda	5	VA	VVA
Ostracoda	3	-	-
Paranephrops planifrons	5	-	-
Paranephrops sp.	5	-	R
Paratya curvirostris	5	-	C
Annelida	1	A	R
Platyhelminthes	3	-	-
Nematoda	3	-	-
Hirudinea	3	-	-
Acarina	5	-	-
Collembola	6	-	-
Mollusca			
Ferrissia sp.	3	R	R
Gyraulus sp.	3	-	-
Physa sp.	3	A	R
Potamopyrgus antipodarum	4	R	R
Sphaeriidae	3	-	R
Number of taxa		16	17
MCI		79	91
SQMCI		4.06	4.81
% EPT_{taxa}		37.5	35.3

Drainage management in New Zealand

A review of existing activities and alternative management practices

SCIENCE FOR CONSERVATION 235

Henry R. Hudson and Jon S. Harding

Published by
Department of Conservation
PO Box 10-420
Wellington, New Zealand

This project is the first of a series of outputs from a multi-agency project that was set up to look at developing more sustainable drain maintenance practices. All parties contributed to a central pool of money that has effectively funded this and other drain projects. The group members were: Clutha District Council, Environment Waikato, Environment Southland, Horizons (Manawatu-Wanganui) Regional Council, Ministry of Agriculture and Forestry, Ministry for the Environment, Nelson City Council, New Zealand Fish and Game Council, Selwyn District Council, Tasman District Council, Te rununga o Ngai tahu, Waimakariri District Council, and the Department of Conservation.

Science for Conservation is a scientific monograph series presenting research funded by New Zealand Department of Conservation (DOC). Manuscripts are internally and externally peer-reviewed; resulting publications are considered part of the formal international scientific literature.
Individual copies are printed, and are also available from the departmental website in pdf form. Titles are listed in the DOC Science Publishing catalogue on the website, refer http://www.doc.govt.nz under Publications, then Science and Research.

ISSN 1173-2946
ISBN 0-478-22521-0

In the interest of forest conservation, DOC Science Publishing supports paperless electronic publishing. When printing, recycled paper is used wherever possible.

This report was prepared for publication by DOC Science Publishing, Science & Research Unit; editing and layout by Ian Mackenzie. Publication was approved by the Manager, Science & Research Unit, Science Technology and Information Services, Department of Conservation, Wellington.

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Drainage management in New Zealand

A review of existing activities and alternative management practices

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ABSTRACT

The literature on drainage maintenance activities, both within and outside New Zealand, was reviewed. Current drainage management activities used by regional and district councils were summarised from responses to a mail survey. The environmental and economic costs of the most widely adopted strategies, specifically: channel excavation, weed clearance by hand and cutter boat, chemical spraying, and controlled grazing, were assessed. Nutrients, chemicals, and soil erosion problems associated with maintenance were considered as causal factors in degrading in-stream habitats, and altering aquatic plant, benthic invertebrate, and fish communities. The literature identified at least 20 native and introduced aquatic plant species in New Zealand drains. Benthic invertebrate communities were generally low in diversity and dominated by snails, worms, and midges, whereas approximately 30 freshwater fish species have been recorded in lowland drains. Alternative drain management strategies from within and outside New Zealand were canvassed, particularly: performance-based management (i.e. measuring improvements in flow and water quality), riparian management (e.g. shading and fencing), naturalisation of drains (i.e. meandering and increasing in-stream habitat). Gaps were identified in New Zealand knowledge of how best to manage drains. There was a basic lack of understanding of the effects of current practices on the hydrology and ecology of drains. While much is still to be learned about specific applications, and the cost-effectiveness of best-management practices in New Zealand, several management principles and practices can be tested and implemented immediately.

Keywords: drainage, management, best practice, drain ecology, aquatic weeds, benthic invertebrates, fish, New Zealand

Hudson, H.R.; Harding, J.S. 2004: Drainage management in New Zealand: A review of existing activities and alternative management practices. *Science for Conservation 235*. 39 p.

1. Introduction

Drainage management is an intrinsic component of successful and sustainable agriculture in most regions throughout New Zealand. Historically, extensive construction of drainage networks has been common practice, so that by 1983 the New Zealand Land Drainage and Rivers Association maintained 4100 km of drains nationally (Hughes 1984). The development of new drainage networks continues. In 2000, Environment Southland alone maintained some 90 community drainage systems on behalf of ratepayers, totalling about 1285 km of channels. This probably represents about only 10% of the total drainage network in Southland (Noel Hinton, Environment Southland pers. comm.). Nationally, the costs of maintenance of drainage networks are considerable. Although no estimate of the total expenditure is available, large councils such as Environment Waikato allocate $1.53 million per annum (with additional spending on capital works for drain upgrading and maintenance of culverts, floodgates, pumping stations, etc.), and Environment Southland budgeted $520 000 in 2000 (Table 1). The actual costs of drainage maintenance nationally are far greater when the hidden costs associated with drains maintained by individual farmers are considered.

TABLE 1. REGIONAL AND DISTRICT COUNCIL-MAINTAINED DRAINAGE NETWORKS, FROM RESPONSES TO THE CAWTHRON INSTITUTE SURVEY, OR FROM ANNUAL PLANS.

COUNCILS	MAINTAINED DRAIN		OTHER DRAINS	TOTAL
	LENGTH (km)	COSTS ($)	(km)	(km)
Hawke's Bay	> 465			
Manawatu–Wanganui	700	200 000		
Marlborough	160			
Northland	n.a.			
Southland	1285	520 000	c. 11 000	c. 12 000
Tasman		420 000*		
Waikato	1800	c. 1 530 000		
Wellington	155	70 000		

* Tasman District Council costs from 1996/97 annual plan. Scheduled maintenance has ceased.
n.a. = Not available.

In this review drainage systems are defined as natural, or artificial channels, sub-surface collection systems, and water control structures that are managed for water drainage purposes on farmland. The main functions of these drains are to remove and control excessive surface water, and lower water tables on farmland.

Three main tenets underpin this review:

- Drains have multiple functions: they should act as efficient, cost-effective channels for removing excess water, while still providing sustainable habitats for flora and fauna
- Adopting effective and sustainable drain maintenance practices requires understanding of both the hydraulic and ecological effects of these practices

- Drains are a part of, and intimately linked to, larger freshwater systems

Popular perceptions about what drainage maintenance activities are appropriate are changing as expectations about farming, and how farming relates to the environment, change. For example, the shift to certified organic farming has involved a change in thinking about the acceptability of the use of chemicals around the farm.

There is also increasing recognition that:

- Many farm drains are environmentally and ecologically important in their own right, and that current drainage management activities may have significant adverse effects
- The statutory requirement to avoid, remedy, or mitigate significant adverse environmental effects stated in the Resource Management Act (1991) may also apply to many drains

These views have the potential to cause conflict between drainage engineers, who might focus on the hydraulics of drainage networks, and environmental advocates (e.g. DOC and Fish & Game) who support minimal disturbance to streams and drains. The ultimate objective of sustainable drainage management should be to rationalise these apparently opposing perspectives through the use of best management practices, based on best available science and adaptive management.

This review summarises the literature and state of our knowledge on several key aspects of drainage management. Much of the information presented here has come directly from discussions with regional, and district council and Department of Conservation staff. The impetus for this review came from concerns raised by DOC, MfE, and MAF that some current maintenance methods are costly, inefficient, and may threaten aquatic species of conservation interest. It is not an exhaustive review of all current management techniques, nor has it been possible to adequately assess all alternative practices. The first part of this document summarises our current understanding of the ecology of drains. The commonest drainage management practices used in New Zealand are discussed. The next section addresses alternative management practices from both within New Zealand and overseas, and assesses the advantages and disadvantages of these alternative practices. Finally, to clarify research priorities for the future, gaps in our understanding of drainage systems are identified, and recommendations for improving current management are made.

2. Ecology of drains

2.1 PHYSICAL HABITAT

Councils manage a wide variety of natural and engineered channels as part of their drainage networks. These drains vary in physical form (e.g. width, depth, channel shape and channel pattern, bed and bank substrates, and gradients), as well as bank vegetation. Other factors that influence the ecological integrity of drains, such as runoff regime and water quality, are also highly variable.

Furthermore, the distance inland, presence of physical barriers (e.g. culverts and floodgates), truncation of the drainage system, and cumulative land uses may influence aquatic fauna. Drains are also usually part of a network that eventually feed into larger rivers and streams, therefore inputs into farm drains are usually cumulative and may directly impact larger downstream waterways. Thus the ecological importance of an individual drain may range from negligible to highly valued, however, its role in the functioning of the wider waterway network to which it is linked must also be considered.

To our knowledge, there has been no systematic assessment of agricultural drains, or of their values as habitat in New Zealand, although methods to undertake such surveys are available (e.g. Platts et al. 1983; Plafkin et al. 1989; Newton et al. 1999). However, preliminary assessments of habitat use, or potential use, are used to guide in-stream activities in Southland (e.g. Hudson 1998a).

General water quality conditions have been assessed in several national and regional surveys of lowland streams (Close & Davies-Colley 1990a, 1990b; Environment Waikato 1998; James et al. 1999; Tasman District Council 2000). However, agricultural streams and drains have been the subject of fewer studies (Marshall & Winterbourn 1979; Harding & Winterbourn 1995; Quinn et al. 1997; Wilcock et al. 1998; Young et al. 2000). Point-source and non-point-source inputs into farm waterways and drains are relatively well documented, and are reviewed by Nguyen et al. (1998).

The major water quality conditions of concern are:

- Elevated nitrogen and phosphorus levels
- Increased suspended sediment and turbidity
- Increased agricultural chemicals
- Low dissolved oxygen
- Increased range of water temperatures

2.2 ALGAE AND MACROPHYTES

Algal communities have been widely studied in streams and rivers throughout New Zealand (Biggs & Price 1987; Biggs 2000), however virtually no work has been documented on agricultural drains. Marshall (1978) conducted one of the few studies in which benthic algal biomass, but not species richness was assessed in a small Canterbury drain. He found relatively low algal biomass (10–330 mg per cubic metre) despite relatively high nitrate, and light levels. However, algal biomass in this study may have been reduced by heavy siltation and grazing pressure from benthic invertebrates.

Aquatic weeds are frequently abundant throughout New Zealand drains, and several studies have identified weed species of concern (e.g. the oxygen weed *Egeria* in Marlborough and Christchurch—Young et al. 2000). Marshall & Winterbourn (1979) found different species dominated the communities in different parts of a Canterbury drain, however, the most abundant species were the pondweed *Potamogeton* spp., the starwort *Callitriche* sp., swamp willow weed *Polygonum* sp., *Azolla* sp., the Canadian pondweed *Elodea* sp., the water milfoil *Myriophllum* sp., the duckweed *Lemna* sp., the watercress *Nasturtium* sp., and the water buttercup *Ranunculus* sp. In Toenepi Stream, Waikato, three main aquatic weed species dominated the drain: a native stonewort *Nitellla hookeri*, *Potamogeton* spp. (a native species *P. ochreatus* and the introduced *P. crispus*), and *Polygonum* sp. (Wilcock et al. 1998). Common aquatic weed species found in drains are listed in Table 2.

TABLE 2. COMMON AQUATIC WEED SPECIES RECORDED IN NEW ZEALAND DRAIN AND FARM WATERWAY STUDIES*.

SCIENTIFIC NAME	COMMON NAME
Alisma spp.	Water plantain
Azolla spp.	Azolla
Bidens frondosa	Beggar's tick
Callitriche spp.	Starwort
Carex secta	Niggerhead
Egeria densa	Oxygen weed
Elodea canadensis	Canadian pond weed
Glyceria fluitans	Floating sweet grass
Lagarosiphon major	Oxygen weed
Lemna minor	Duckweed
Mimulus guttatus	Monkey musk
Myriophyllum spp.	Water milfoil
Nasturtium spp.	Watercress
Nitella hookeri	Nitella (Stonewort)
Phormium tenax	New Zealand flax
Polygonum spp.	Swamp willow weed
Potamogeton spp.	Curly leaved pondweed
Ranunculus spp.	Water buttercup
Riccia fluitans	Liverwort
Typha orientalis	Raupo

* Burnet 1972; Edwards & Moore 1975; Marshall & Winterbourn 1979; Wilcock et al. 1998; Goldsmith 2000; Young et al. 2000.

2.3 BENTHIC INVERTEBRATE COMMUNITIES

Several studies throughout New Zealand have described the benthic invertebrate fauna of drains. Marshall & Winterbourn (1979) recorded 34 taxa at 4 sites where the benthic communities were dominated by 5 species of worms (*Tubifex* sp., *Limnodrilus* sp., *Lumbriculus* sp., *Potamothrix* sp., and *Nais* sp.), the snails *Potamopyrgus antipodarum* and *Sphaerium novaezelandiae* and the common New Zealand amphipod *Paracalliope* sp. High invertebrate densities are not uncommon in drains, particularly where nutrient and light levels and plant biomass are high. Marshall & Winterbourn (1979) recorded densities of 280 000 animals per square metre at their most nutrient-enriched site. In Southland, Ryder (1997) found 30 invertebrate species in drains in the Oteramika catchment with communities dominated by amphipods, particularly *Paracalliope* sp., and *Paraleptamphopus* spp., which reached densities of 129 000 per square metre. The snail *Potamopyrgus antipodarium* and the mayfly *Deleatidium* were also abundant. In a Waikato drain, Scarsbrook et al. (2000) and Wilcock et al. (1998) found 31 species, with communities dominated by snails, particularly *Potamopyrgus* and to a lesser degree *Gyraulus* and *Physa*. Other important invertebrates included sandflies (*Austrosimulium* spp.), worms, the caddisfly *Oxyethira albiceps* and non-biting midges (Chironimids). In agricultural streams and drains associated with Spring Creek, Marlborough, Young et al. (2000) recorded 32 species of aquatic invertebrates. These communities were generally dominated by amphipods, worms, and *Potamopyrgus*, however in tributaries subject to drain maintenance amphipods were greatly reduced in abundance.

2.4 FISH COMMUNITIES

Most migratory freshwater fish species (e.g. whitebait and eels) may migrate through or use agricultural drains for temporary habitat, refuge, or spawning. New Zealand's three eel species, the freshwater crayfish or koura, freshwater shrimp, and most of the whitebait species and salmonids have been frequently observed in lowland farm waterways (Young et al. 2000). Several threatened species (e.g. the Canterbury mudfish *Neochanna burrowsius*, the Brown mudfish *Neochanna apoda*, and the Giant kokopu *Galaxias argenteus*) have been found in drains, particularly where preferred habitat, such as wetlands, no longer exist (Skrzynski 1968; Cadwallader 1975; McDowall 1990; Goldsmith 2000).

Interrogation of New Zealand's freshwater fish database (a national database managed by NIWA) provides an indication of species likely to be found in agricultural lowland regions throughout the country, while Table 3 lists 29 species recorded from drains.

TABLE 3. FISH FOUND IN DRAINS AND DRAINAGE CANALS IN NEW ZEALAND STUDIES*.

SCIENTIFIC NAME	COMMON NAME	SCIENTIFIC NAME	COMMON NAME
Aldrichetta forsteri	Yelloweyed mullet	*Gobiomorphus cotidianus*	Common bully
Ictalurus nebulosus	Catfish	*Gobiomorphus goboides*	Giant bully
Anguilla australis	Shortfinned eel	*Gobiomorphus breviceps*	Upland bully
Anguilla dieffenbachii	Longfinned eel	*Mugil cephalus*	Grey mullet
Arripis trutta	Kahawai	*Neochanna apoda*	Brown mudfish
Carassius auratus	Goldfish	*Neochanna burrowsius*	Canterbury mudfish
Ctenopharyngodon idella	Grass carp	*Neochanna diversus*	Black mudfish
Cyprinus carpio	Koi carp	*Paranephrops*	Koura
Galaxias anomalus	Roundhead galaxias	*Perca fluviatilis*	Perch
Galaxias argenteus	Giant kokopu	*Retropinna retropinna*	Common smelt
Galaxias fasciatus	Banded kokopu	*Rhombosolea leporina*	Yellowbelly flounder
Galaxias maculatus	Inanga	*Rhombosolea retiaria*	Black flounder
Galaxias vulgaris	Common galaxias	*Salmo trutta*	Brown trout
Gambusia affinis	Mosquitofish	*Scardinius erythrophthalmus*	Rudd
		Tinca tinca	Tench

* McDowall & Lambert 1996; Ryder 1997; Goldsmith 2000; Young et al. 2000; and R.R. Strickland pers. comm.

2.5 MANAGEMENT MEASURES

Most of the regional councils recognise the use of coastal drains by fish and wildlife, and usually avoid maintenance during spawning, nesting, and migration periods. Figure 1 indicates the main spawning, nesting, and migratory periods of fish and bird species commonly associated with drains. However, although these species are known to use drains, no literature exists which identifies or has classified environmentally sensitive drain channel habitats, or the actual or potential use of these habitats. Similarly, few attempts have been made to assess the impacts of drain maintenance on aquatic communities. In contrast, monitoring of effects of drainage management are common place overseas (e.g. British Columbia—Lalonde & Hughes-Games 1997).

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

Figure 1. Summary of likely fish spawning and riverine bird nesting periods for species found in farm drains in the Southland region (compiled by Hudson 1998b).

3. Current drainage management practices

3.1 WHY MAINTAIN DRAINS?

Successful land drainage ultimately depends on the ability of drains to remove excess water and yet maintain soils in a physical, chemical, and biological condition favourable for crop growth and grazing (Lalonde & Hughes-Games 1997). Hence, the primary aim of drain maintenance is the removal of excess water (often surface run-off) quickly and efficiently. Maintenance is required because sediment, nutrients, and farm chemicals associated with this run-off accumulate in the drains. It is the addition of these inputs and the response of aquatic plants to high nutrients, sediment and light that are responsible for the poor hydraulic performance of many drains.

3.2 MAINTENANCE PROBLEMS

As part of this report a survey of current drain maintenance practices used by regional and district councils was conducted by the Cawthron Institute (see Appendix 1). Findings from this survey indicated that council staff view clogging of drains, and associated reductions in their hydraulic capacity to be the major problem in drainage maintenance in New Zealand. Council staff suggested that reduced capacity is usually caused by excessive aquatic and riparian plant ('weed') growth, sediment infilling, and debris accumulation, however, there does not seem to be any New Zealand studies that quantify the loss of hydraulic capacity from weed growth or sediment build up. Hudson (1998b) calculated the effects due to sediment and weed build up, based on empirical relations for hypothetical drains. However, the hydraulic characteristics of aquatic and bank vegetation are poorly documented, and effects appear to be highly variable. For example, aquatic weeds may be hydraulically rough at low flow, thus significantly reduce stream flow, but at high flow the plants bend over and are hydraulically smooth, thus increasing drain capacity.

Plant growth, sediment infilling and debris accumulation can all significantly reduce the hydraulic capacity of waterways by changing the streambed roughness, cross sectional area and/or slope of a watercourse. Another important cause of reduced drain capacity is channel instability that usually results from excessive bank erosion or stock trampling.

Although degraded water quality is not generally considered a drainage management problem, drains collect runoff, sediment, and contaminants (e.g. pesticides and fertilisers) from surrounding land. These contaminants strongly influence the plant and animal life that can exist in the drain, and impact downstream freshwater systems into which drains discharge.

3.3 MANAGEMENT STRATEGIES

Drain maintenance is either corrective (e.g. repair of floodgates) or preventative (e.g. riparian planting). One of the key decisions facing managers is when to undertake preventative maintenance. Currently, each regional council has different criteria about when maintenance is required and how the effectiveness of maintenance will be measured. In North Waikato, drain maintenance is considered effective if 38 mm of runoff is flushed from the catchment within 24 hours (Environment Waikato 2000). Whereas in the Heretaunga Plains, 50 mm/ha/day of runoff is expected from gravity systems, and 32 mm/ha/day for pumped systems. The availability of funds may determine the frequency and type of drain cleaning. Frequently informal 'performance based' methods are used to decide when to carry out cleaning—for example, a decision to clean a drain because 'significant' weed growth is perceived to be a problem, or when a land owner complains about the condition of their drain, or when tile drain outlets are not flowing freely.

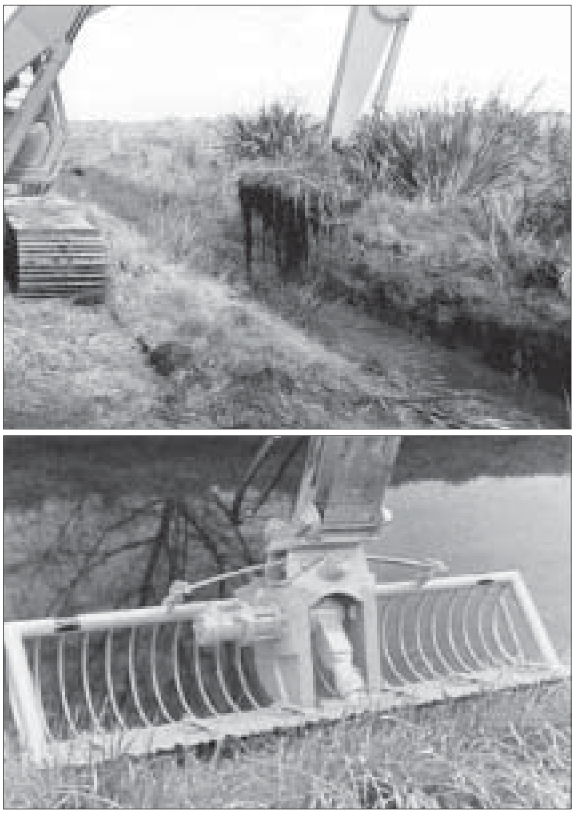

Figure 2. Normal excavator buckets are used to remove weeds and sediment (*top*), but weed buckets are often recommended (*bottom*).

Regional councils, such as Bay of Plenty, Hawke's Bay, and Waikato have instituted in-house codes of practice for drain maintenance. Canterbury and Marlborough have formal environmental guidelines for river management, and several other regions are in the process of developing guidelines (e.g. Manawatu–Wanganui and Southland). For some maintenance activities New Zealand operator guidelines are available (e.g. chemical spraying) and the use of certified applicators is standard practice. In some cases councils state their requirements in the spray or diggers contracts (e.g. contractors are to avoid spraying directly into the water), but these may not include specific environmental practices. Frequently, management practices are based on anecdotal evidence or trial and error, without supporting scientific documentation or references.

The intensity and frequency of cleaning practices vary considerably from region to region. When drains are maintained to increase hydraulic capacity (normally by increasing the width, and depth of the channel), the bed and banks are excavated (Fig. 2). In some cases, the council's maintenance specification simply states: 'The cleared drain shall be free of vegetation and obstructions which will impede the flow of water' (Waitaki DC for road drains). During routine maintenance, it is common practice to only remove sediment and or plants from a portion of the drain (e.g. the bed and one bank), and in some cases, only the bed of the drain is cleared, and disturbance to the banks is avoided as far as practicable (see Fig. 3 next page) (Crabbe & Ngapo 2000). Maintenance may be staggered so that small sections are cleared in successive years. However, in some regions the entire length of drain may be cleared at one time.

Figure 3. Excavated weed and sediment should be placed close to the bank to enable eels and crayfish to return to the drain.

3.4 COMMON PRACTICES

The following section summarises the main practices currently used by regional and district councils. Appendix 1 includes a summary of regional and district council survey responses. These fall into three broad categories: mechanical maintenance, chemical control, and biological control.

Mechanical maintenance includes:
- Channelisation and excavation of weeds and sediment
- Manual removal and cutting of weeds
- Weed cutting by boat
- Mowing riparian margins

Chemical control includes:
- Spraying of aquatic and riparian plants

Biological control includes:
- Stock grazing of riparian areas
- Control of aquatic weeds with Grass carp

New Zealand and overseas experience indicates that no single management practice is consistently better than others, nor will one management practice (e.g. use of herbicides or hydraulic excavators) be appropriate for all situations. Rather, each technique should be considered a tool in the manager's toolbox (Madsen 1997). A suite of best management practices should to be developed to address specific site conditions, economic, environmental, and technical constraints, and priorities and management goals in each drain.

3.5 MECHANICAL CONTROL

3.5.1 Channelisation, and excavation of weeds and sediment

Brookes (1988) reviewed the international literature on the impacts of channelisation, weed growth and sediment of streams and rivers, and the major findings of these effects on habitat and benthic invertebrates are summarised in

Table 4. Brookes (1988) identified a number of consistent direct and indirect effects.

Direct effects include:

- Sediment levels and aquatic weed biomass were reduced
- Turbidity in the drain increases dramatically for several hours as bed sediment becomes suspended
- The physical morphology and flow characteristics of the drain are changed depending on the extent and method of excavation
- Loss of in-stream habitat (e.g. substrate is removed)
- Invertebrates, fish, eels, and crayfish are physically removed with the sediment and weeds

TABLE 4. REVIEW OF STUDIES ON THE EFFECTS OF CHANNELISATION, EXCAVATION AND WEED CUTTING ON IN-STREAM HABITAT AND BENTHIC INVERTEBRATE COMMUNITIES (after Brookes 1988).

ACTIVITY	EFFECT
Excavation	Physical removal of benthic invertebrates
	Changed substrate effects invertebrate recovery
	No effect on invertebrates, where habitat in not changed
Channelisation	Siltation smothering invertebrates or changing communities
	Degraded substrate resulting in habitat loss and reduced benthic invertebrates
	Degraded habitat (loss of pools and riffles) and reduced benthic invertebrates
	Altered invertebrate drift due to poor substrate
Weed cutting	Increased drift (170 fold)
	Increased abundance of some species decreased others

Indirect effects include:

- Disturbance of sediment re-suspends agricultural chemicals and sprays that have accumulated in the sediment
- Loss of food for bird and fish species
- The removal of all weeds results in loss of overhead cover essential for regulating water temperature
- Loss of in-stream cover and habitat for benthic invertebrates and fish (e.g. giant kokopu, shrimp)
- Disturbance of drain bed, including removal of cobbles and gravels, which are essential for spawning sites of some fish species (e.g. trout)
- Physical damage to the drain margins and banks by the digger, increasing bank instability and erosion
- Spread of some aquatic plant species that grow from fragments disturbed by the excavator

Sediment accumulation and re-suspension can result in significant problems. The impacts of sediment and turbidity on freshwater communities and habitats have been reviewed by several researchers (e.g. Cordone & Kelly 1961; Ryan 1991; Waters 1995; Wood & Armitage 1997).

Major impacts include:

- Reduced primary productivity as turbid waters reduce light penetration, suspended sediment can also damage aquatic plant leaves and stems, and moss due to physical abrasion
- Smothering of algae, and aquatic plants, with fine material and reducing their quality as a food resource for benthic invertebrates
- Reducing feeding of fish and benthic invertebrates
- Altering the magnitude of invertebrate drift
- Infilling pools and riffles with sediment that reduces habitat for drain biota
- Clogging of interstitial bed material further reducing habitat quality

While the impacts of sediment on stream systems have been the subject of a number of studies, the effects of bed disturbance during excavation are not known. Brookes (1988) reported significant deposition following channel clearing in Wallop Brook in England, while in the River Wylye sediment deposition was negligible when cleaning operations coincided with a period of high flow. Attempts to quantify the effects of sediments in drains have been rare in New Zealand, and the few available studies are not definitive. Wilcock et al. (1998) assessed the effect of mechanical excavation of an 80 m reach in a Waikato drain. The excavator widened the channel, lowered the water level, and removed approximately 56 m^3 of sediment. This caused short-term increases in turbidity and ammonia (3–4 hours) while dissolved reactive phosphate and nitrate levels were reduced. After excavation, willow weed (*Polygonum* sp.) was still absent after six months, whereas densities of the Curly leaved pondweed *Potamogeton* sp. recovered. Benthic invertebrates were affected by macrophyte and sediment removal, in particular, densities of the snail *Gyraulus* sp. were reduced by 90%.

Goldsmith (2000) sampled three mechanically cleaned, two chemically sprayed (glyphosate and diquat), and four control sites before and six weeks after treatment. Mechanical cleaning significantly reduced plant coverage (mainly Sweetgrass *Glyceria*, *Potamogeton* and watercress *Nasturtium*), but did not cause significant changes in individual species or in water depth, velocity, or median substrate size. No difference was found in fish species richness or density six weeks after treatment. Five fish species were commonly found including long finned eel (*Anguilla dieffenbachia*), upland bully (*Gobiomorphus breviceps*), common galaxias (*Galaxias vulgaris*), common bully (*G. cotidianus*) and brown trout (*Salmo trutta*), while inanga (*Galaxias maculatus*), giant bully (*G. goboides*), giant kokopu (*Galaxias argenteus*) and short finned eel (*A. australis*) were also present at some sites.

Although hydraulic excavators were commonly used to remove sediment from drains, some councils viewed them as the 'last resort' for weed control. Where weeds trap sediment, and the ability of the drain to flush water is reduced, an excavator bucket may be used to remove both plants and sediment (Fig. 2). Excavators can usually extend across drains that are several metres wide, enabling operations to be carried out from one bank only and thus minimising impacts along the drain banks. In wide drains draglines were frequently used (i.e. wire rope which is dragged along the bed to remove weeds). McDowall & Lambert (1996) concluded that annual 'drag-lining' in the Oteramika Stream destroyed virtually all fish habitat and caused direct fish mortality, resulting in significant reductions in fish stocks.

Weeds and sediment were sometimes deposited close to the riverbank to enable eels and crayfish to escape back to the drain (Fig. 3). The spoil was later removed or spread across farm fields. In some cases, spoil was left alongside the drain. These practices vary depending on council guidelines or the contractor's attitude.

The timing of operations were highly variable (Appendix 1). In some regions, spawning and fish migration periods were avoided (e.g. Bay of Plenty and Southland), however, in many areas, work was reactive and undertaken following complaints by landowners.

In Southland, weed and sediment excavation typical costs averaged \$0.55 per metre (Hudson 1998a), \$0.82 per metre in the Waikato (Environment Waikato 2000), and \$0.80–\$1.20 per metre in Hawkes Bay (Norm Olsen pers. comm.). However, drain clearing costs were as high as \$2.80–\$8.37 per metre in Marlborough (Williman & Bezar 1999). These costs varied with access, size of the drain, and details of work required. Additional costs may be associated with disposal of spoil, if it is not left along the drain margin or incorporated into adjacent paddocks. In Hawke's Bay, disposal costs (cart and dump) range from \$1.30 to \$2.10 per metre (Norm Olsen pers. comm.).

3.5.2 Manual removal and cutting

Manual methods of weed removal are used worldwide for small drains and canals (Cooke et al. 1993; Madsen 1995). Hand removal usually involves pulling of weeds, and is frequently limited to sensitive areas with poor access (Cooke et al. 1993). It generally causes significantly less disturbance to banks and the drain bed, and is frequently used in sites sensitive to public use (Cooke et al. 1993). In New Zealand most councils manually clear some drains or drain reaches.

Two main methods are employed:

- Pulling of individual plants by hand
- Using hand-operated machines to cut vegetation (e.g. hand scythes, brush cutters, and chainsaws for brush and trees)

Hand pulling of plants physically removes the roots, which reduces the chance of regrowth. Although in theory it is possible, in reality, manual removal rarely results in eradication of the plants from a reach, because complete root removal is unlikely. In riparian zones, trees and scrub are cut, so that the root structure remains intact to hold the soil in place. Trees are burnt or removed off site and regrowth may be prevented by applying a chemical to the stump.

The annual cutting of aquatic weeds has been shown to significantly effect benthic invertebrate communities (Kern-Hansen 1978; Pearson & Jones 1978; Wilcock et al. 1998). Weed cutting on the Hull River in England resulted in the direct removal of large numbers of individuals with the weed and increased drift rates of species associated with weeds (Pearson & Jones 1978), while weed cutting in a Danish stream resulted a 1700% increase in invertebrate drift rates with 24 700 animals per cubic metre (Kern-Hansen 1978). This increase in numbers in the drift was attributed primarily to species associated with weeds (e.g. caddis, beetle, and dance flies), and continued for several days after cutting. Where bed disturbance occurred, invertebrate recovery may be slow (e.g. Kern-Hansen 1978), however, if there is little or no bed disturbance, then rapid recovery has been recorded (Pearson & Jones 1978). Large-scale removal of weeds changes the habitat, and has been shown to remove semi-aquatic vertebrates, and possibly fish eggs (e.g. inanga eggs) on riparian plants (Mitchell 1990). However, the impacts of selective harvesting in New Zealand drains have not been documented.

Few councils provided information on timing of operations in their responses to the Cawthron survey. Costs were similar to hydraulic excavators (e.g. an average cost of $0.67 per metre—Environment Waikato 2000), but actual costs are dependent on the degree of invasion by weed, access, and size of the drain. Marlborough District Council reported costs ranging from $4.49 to $7.74 per metre (Williman & Bezar 1999).

3.5.3 Weed cutter boat

Weed cutter boats were used for aquatic plant removal by Bay of Plenty and Hawke's Bay Regional Councils, and Christchurch City Council. Crabbe & Ngapo (2000) describe a purpose-built boat used to trim aquatic weeds to just above the bed level, across a channel. Weed cutter boats typically use a sickle-bar cutting blade. Cutting is quick, but may leave large mats of plants which can result in re-establishment or spread of the plant. It also creates a floating obstacle which may wash up on shorelines, and/or cause water-quality problems through decomposition (Madsen 2000). Because of these problems, cut plants are frequently removed. Cut weed is disposed of on land where practicable, or the material is allowed to wash downstream. Methods for harvesting (removing) cut weeds from the drain were not addressed in the survey, and no timings were specified, but cutting usually occurred twice per year. Costs varied with drain width and amount of weeds, but clearing which regularly maintained channels up to 3 m wide in Hawke's Bay typically cost $0.10–$0.20 per metre. For channels more than 7 m wide the costs were $0.40–$0.60 per metre. Collection, carting and disposal of cut weed typically cost $0.10–$0.50 per metre (Norm Olsen pers. comm.).

3.5.4 Mowing riparian margins

Mowing riparian margins was common practice. Long-reach mulching mowers were frequently used on steeper-sided drains and embankments. Hastings District Council undertook mowing 3 times per year (September, December, and April), while Hawke's Bay Regional Council mowed 2–4 times per year (or more frequently for aesthetic reasons). Generally, a council aimed to maintain grass in any dry drain beds and along drain margins (Olsen et al. 2000). Tractor-mounted long-reach mowing costs vary with drain depth and range from $0.05–$0.20 per metre. For sites with poor access, portable scrub-bar cutters were used at least once annually. Costs were typically $0.50–$0.60 per metre (Norm Olsen pers. comm.).

3.6 CHEMICAL CONTROL

Chemical spraying was the commonest and cheapest vegetation control method used by councils. Environment Waikato (2000) reported chemical costs averaging $0.03 per metre, with application costs varying, depending on access (total costs averaging $0.08–$0.11 per metre). In Hawke's Bay, spraying drains up to 3 m wide from a tractor-mounted hydraulic boom cost $0.10–$0.20 per metre (Norm Olsen pers. comm.), whereas Marlborough District Council reported costs of $0.28 per metre (Williman & Bezar 1999).

Cooke et al. (1993) noted that historically there have been widespread concerns over the use of chemicals for aquatic plant control. However, the review process for pesticides used in water has received considerable attention in recent years (Madsen 2000). The major concerns about the use of chemicals are associated with human health, potential biomagnification in wildlife, and persistence in the environment. Wade (1994, 1995) reviewed the potential impacts of herbicides on the stream system, which include death or damage to non-target plants, and possible cumulative downstream effects.

The main chemicals used by councils were Glyphosate (e.g. Roundup) and Diquat dibromide (e.g. Diquat, Reglone, Reward, and Torpedo), while Gallant may be used for roadside ditches.

Glyphosate is a systemic herbicide for use on emergent macrophytes and bank-side vegetation. The herbicide is translocated throughout the plant, which often has the effect of killing the entire plant. It is not effective on submersed plants. Environment Waikato used Glyphosate 360 with the addition of an organosilicone penetrating agent because of the silt on the vegetation (Guy Russell pers. comm.). Glyphosate is readily adsorbed by soil, but it is supposedly not persistent (average half life of 47 days) (Wauchope et al. 1992; WSSA 1994). However, the herbicide could be transported with soil particles in runoff, but Malik et al. (1989) estimated that less than 2% of the applied chemical was lost to runoff. In a North American study its half-life in pond water ranged from 12 days to 10 weeks (EPA 1992). Glyphosate was slightly toxic to aquatic invertebrates (WSSA 1994), and wild birds (Kidd & James 1991; WSSA 1994), but non-toxic to fish and mammals (Monsanto 1985, EPA 1987; Malik et al. 1989). A variation (Rodeo) was frequently used in aquatic situations.

Diquat dibromide was a quick-acting contact herbicide and plant growth regulator that caused injury only to the parts of the plant to which it was applied. It is reportedly non-selective, and will affect 'non-target' plants (Howard 1991), however, there was some indication that it may be selective to some New Zealand species. It is rapidly absorbed from the surrounding water and concentrated in the plant tissue so that aquatic weeds are affected even at low concentrations (NLM 1995). Peirce (1998) noted that submerged plants were perhaps the hardest aquatic weeds to kill because chemicals used need to be maintained at a sufficiently high concentration in the water for them to become effective. Diquat is rapidly absorbed by submergent plants, but without sodium alginate in the formulation it is less effective in water velocities > 0.03 m s^{-1}. However, anecdotal observations of applications in faster waters (without and without alginate) indicate that it may be equally effective. It is strongly, and rapidly, adsorbed and inactivated by clays and other organic particles (Wade 1994), hence the performance of Diquat is greatly reduced in turbid waters or waters where plants are covered by silt. High water hardness also reduces the uptake of Diquat. Diquat dibromide's half-life is less than 48 hours in the water column, but it may persist for 160 days in sediments (Gillett 1970; Tucker 1980).

Diquat dibromide ranged from slightly to moderately toxic to birds (EPA 1986) and has shown conflicting results in some studies on fish and benthic invertebrates. Pimentel (1971), Simonin & Skea (1977), and Johnson & Finley (1980) suggested little effect, however, in at least one New Zealand study, toxic effects on benthic invertebrates were indicated (Young et al. 2000). NLM (1995) stated there was little or no bioaccumulation of diquat dibromide in fish.

As Paraquat (another spray historically used in drain maintenance) is no longer approved for use in New Zealand waters we have not covered its effects here.

3.7 BIOLOGICAL CONTROL

3.7.1 Controlled grazing

Controlled grazing practices along waterways in New Zealand have been reviewed by Hicks (1995). Although controlled grazing by livestock such as sheep, cattle, and geese, can be very effective in controlling bank vegetation (ASCE 1991), there are some significant disadvantages:

- Livestock usually preferentially graze on the most palatable species, which favours survival of less palatable, and often nuisance weeds
- Livestock can be significant seed dispersers, and may spread weeds to drains from adjacent fields
- Livestock defecate, urinate, and trample in and near drains, which can impact on water quality
- High stocking rates, concentrated activity (e.g. stock crossings), and wet conditions can cause substantial bank and bed damage, which result in increased erosion and sedimentation

The impacts of stock grazing can be highly variable and dependent on the livestock type—for example, deer wallow in shallow pools (Fig. 4), while sheep generally avoid water—and on site conditions (Williamson et al. 1990). The overall benefit of excluding livestock from streams and drains is usually high. Environment Waikato (2000) found that drains with stock excluded needed clearing less frequently. They attributed this to reduced inputs of effluent and sediment. Drain cleaning has shifted from a 2–3 year cycle to a 10–15 year cycle (Guy Russell pers. comm.).

3.7.2 Control of aquatic weeds with grass carp

Chinese grass carp (*Ctenopharyngodon idella*) were introduced into the Waikato in the early 1980s. Environment Waikato have attempted controlled releases at 6 sites over the last 10 years and 4 sites in 2000 (Guy Russell pers. comm.). Grass carp were suggested as a possible biocontrol in New Zealand by Rowe & Schipper (1985) and MfE (1992). They reported that grass carp have been shown to be capable of eradicating nuisance plant growths in standing waters, and suggested they might effectively control weeds in small water bodies.

The effectiveness and survival of grass carp is strongly influenced by water temperature, dissolved oxygen levels, and water quality (Rowe & Schipper 1985). Carp mortality was high in an agriculturally polluted stream in New Zealand (Rowe & Schipper 1985). The majority of carp died in a trial in Churchill East drain in the Waikato, presumably as a result of low dissolved oxygen levels (Hicks pers comm.). Alberta Agriculture (1998) reported that the amount of food consumed by grass carp is directly related to temperature. At 13°C, grass carp consumed 5% of their body weight per day while at temperatures of 18–25°C, they consumed 24% of their body weight. Feeding ceased at lower temperatures, indicating that carp may be ineffective as a biocontrol agent in South Island waterways. Edwards & Moore (1975) examined effects of stocking two-year-old grass carp (*Ctenopharyngodon idella*) in a farm drain over summer. Water temperature ranged from 13°C to 20°C with a mean temperature of 16.5°C. Initially, 25 carp were introduced for 3 months and a further 20 carp were added for the final 2 months, giving rates of 350–650 kg per hectare. The carp reduced standing crops and percentage cover of *Callitriche* sp. and *Nasturtium* sp., but had no effect on *Polygonum* sp.. It seemed the fish preferentially ate *Callitriche*, then *Nasturtium* and finally *Polygonum* only when the other two species had been reduced. The release of 250 carp into the Churchill East drain resulted in major reductions in submerged macrophytes such as *Certophyllum*, and *Potamogeton* while emergent species, such as *Glyceria* increased (Wells et al. 2000). Similarly, Clayton et al. (1995) found that sterile triploid grass carp removed > 99% of the *Hydrilla verticillata* biomass from a small lake in Hawke's Bay over 17 months. Maintenance of fish browsing pressure for a further 5 years was recommended to minimise risk of tuber regrowth. When the *Hydrilla verticillata* was effectively removed, the carp began to feed on marginal emergent plants such as *Typha orientalis*.

Figure 4. The view upstream (*top*) of a paddock where grazing of the stream area has been controlled, and the view downstream (*bottom*) of a deer paddock where grazing of the stream area has been uncontrolled.

In a 2 km reach of the Mangawhero Stream (Aka Aka–Otaua Plains), Rowe & Schipper (1985) demonstrated that 100% weed control could be achieved with cost savings of 20% over herbicides. Current costs were not reported by the councils. Trials in the Waikato indicate that grass carp may be cost-effective and provide benefits by reducing the frequency of machine and hand clearing (Russell pers. comm.). In addition, some weeds are particularly difficult to control with chemicals or mechanically (e.g. *Hydrilla verticillata*—Clayton et al. 1995). *Hydrilla verticillata* spreads readily through fragmentation; therefore, using mechanical controls while the plant is still invading tends to increase its rate of spread (WSDE 2000).

The value of grass carp as biocontrols has still not been fully determined, nor has the effect of this species on wider freshwater communities. When introduced into new environments, exotic species, such as grass carp, have the potential to introduce diseases into existing fish population, and displace existing species by removing aquatic plants which act as food and breeding habitats (Alberta Agriculture 1998). This risk to existing fish populations has been recognised in current trials (Bay of Plenty 2000).

4. Impacts of other drainage management practices

In this section the impacts of other management practices (including 'no maintenance') are reviewed, based on the New Zealand experience and the international literature.

4.1 BARRIERS

Many drainage networks have physical barriers, including:

- Culverts
- Weirs
- Current operated flapgates (floodgates)
- Pump stations

Many New Zealand freshwater fish species are migratory and require unimpeded access to the sea. Some are relatively poor climbers so overhanging culverts and weirs can act as significant barriers to migration. Furthermore, Roper-Lindsay (1991) noted that flood-gates were disruptive to fish that rely on the saltwater–freshwater gradient for navigation and habitat selection. Some whitebait species lay their eggs at the point where high tides meet freshwater, and floodgates present an abrupt transition from salt to fresh water. She suggests that in the Styx River, near Christchurch, the lack of an extended saltwater–freshwater transition may limit whitebait spawning, despite the presence of large adult galaxiid populations.

4.2 NO MANAGEMENT

When evaluating management techniques there is a danger that doing nothing may seem to be a safer option, with fewer consequences (Madsen 2000). However, when controlling introduced pest species, the environmental consequences of doing nothing may be high, possibly even higher than the effects of active management techniques. Unmanaged, these species can have significant negative effects on water quality, native plant distribution, abundance and diversity, and the abundance and diversity of benthic invertebrates and fish (Madsen 1997). By comparison, indigenous aquatic plant species rarely become pests.

5. Alternative management concepts and practices

In this section alternative management concepts and practices which have been instituted or trialled overseas are reviewed. ‘Alternative’ in this regard refers to concepts or practices that are not widely used or well publicised in New Zealand, and have not been discussed in previous sections.

5.1 PERFORMANCE-BASED MANAGEMENT

In New Zealand drainage maintenance has traditionally focused on maximising hydraulic efficiency (i.e. draining floodwaters quickly—Fig. 5). However, the effectiveness of drain maintenance in terms of determining the level of maintenance required to achieve acceptable flow control have rarely been assessed (Dunderdale & Morris 1996; Thoreson et al. 1997). As a result, the effectiveness of drainage maintenance is frequently reported as a ‘process’ measure (e.g. how much drain is cleaned) rather than a ‘performance measure’ (e.g. how has drainage efficiency increased), and what gain in agricultural productivity resulted from the maintenance. Currently, no studies are generally available which have documented the economic costs of process-based management compared to farm productivity benefits.

Figure 5. A roadside drain from which all in-stream and riparian vegetation has been removed, leaving no habitat for aquatic wildlife and biota.

The disadvantage of not linking drainage maintenance to hydraulic efficiency, and to agricultural productivity, is that drains are cleaned too frequently, or not frequently enough, and that the value and effectiveness of drain maintenance is not actually known (Dunderdale & Morris 1996; Lalonde & Hughes-Games 1997; Thoreson et al. 1997).

5.2 INTEGRATED MANAGEMENT

Drainage management strategies often focus on problems rather than solutions. For example, excessive sediment deposition in a drain is addressed by excavating the sediment. While this may be one way of dealing with the immediate problem, it does nothing to address the cause, which may be bank erosion and soil loss from farmland runoff.

Cost-effective and environmentally friendly drainage management requires a combination of best farming practices on the land as well as in the waterways. Ministry for the Environment (MfE 1997, 2000) and Ministry of Agriculture (Haynes 1995; Hicks 1995), and the EPA (2000) promote integrated land, channel margin, and in-stream management using a broad range of management measures that address both the problem and its causes.

Management measures in an integrated drainage programme include:

- Controlling soil loss and contaminants through stock, crop and effluent management
- Controlling farm soil erosion and contaminants with buffer strips along drain margins
- Reducing nutrients and sediments in streams with nutrient stripping and sediment control measures
- Controlling bed and bank erosion by improved channel design and erosion control measures e.g. with the construction of sediment traps
- Using a combination of practices (e.g. chemicals, grazing and mechanical harvesting) for the control of weeds in an integrated pest management programme

5.3 CONTROLLED DRAINAGE

'Controlled' drainage involves managing drains across a range of water levels (i.e. not just managing flood flows). This method has been adopted overseas where the aim is to manage water levels over a prescribed range, rather than trying to maximising outflow (NRCS 1990; ASAE 1994; Lalonde & Hughes-Games 1997). Controlled drainage, which might be achieved with adjustable weirs or variable weed clearance protocols, enables drain managers and farmers to:

- Store and manage infiltrated rainfall for more efficient crop production
- Improve surface water quality by increasing infiltration and reducing the intensity of runoff
- Reduce nitrates in the drainage water by enhancing conditions for de-nitrification
- Reduce subsidence and erosion of organic soils
- Control water levels for sub-irrigation (where water is transmitted from the controlled water table through the subsurface drains to the plant roots)
- Maintains in-stream habitat for aquatic life
- Maintain water levels in adjacent wetlands and lakes (e.g. in Manawatu–Wanganui and Waikato)

Manipulation of water levels, to flood or dry out the drain, has been used as a method of weed control for *Hydrilla* (Ludlow 1995), Eurasian water milfoil (Siver et al. 1986), and other milfoils or submersed evergreen perennials (Tarver 1980).

5.4 CHANNELISATION

The adverse effects of channel engineering, particularly channelisation, have been well documented and have lead to an evolution in river management practices (see review in Brookes 1988). As a result, successful attempts have been made to reduce the negative impacts of channelisation (Brookes 1988, 1989, 1992; Newbold et al. 1989; DEPA 1995; Madsen 1995; Benstead et al. 1997; Lalonde & Hughes-Games 1997; Purseglove 1998). These practices include:

- Limiting cleaning of channels to occasions when drainage efficiency is significantly reduced
- Leaving an undisturbed continuous strip of emergent plants and macrophytes along one bank of the drain
- Excavating one bank and retain vegetation on the other bank
- Avoid excessive drain widening
- Retain/create channel sinuosity and pools and riffles (Fig. 6)
- Selectively cutting macrophytes to create a meander pattern in a straight channel
- Creating by-pass channels, which will take excess flows during floods
- Installing temporary silt barriers (such as straw bales or silt dams) to control sediment movement downstream during excavations
- Constructing sediment traps in the bed to limit the area requiring routine sediment removal
- Manipulating channel shape (e.g. sinuous V-shaped thalweg) to concentrate flow and maintain a weed and sediment free path,
- Creating two-stage floodways in which the existing low flow channel is retained and the floodplain is excavated to provide floodway capacity
- Reducing bank slopes to increase flood capacity and provide water quality and habitat benefits

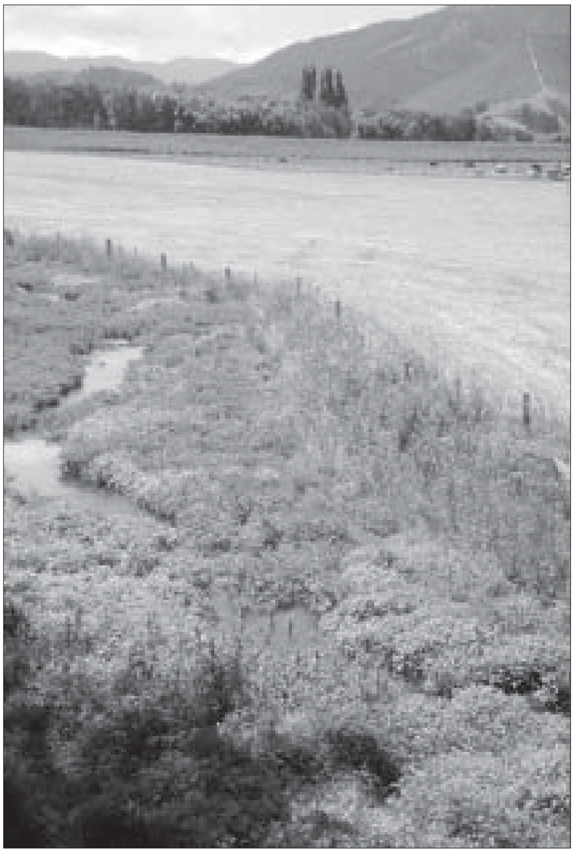

Figure 6. An ideal sinuous channel and riparian fencing on a dairy farm in Marlborough.

DEPA (1995) reported that selective clearing of weeds, and creation of meandering channels resulted in less disturbance to the stream biota (see Fig. 7, next page) and a significant increase in trout numbers in Idom Å Stream, Denmark. Generally, however, the evidence of successful flow management by selective weed control is anecdotal. For example, Madsen (1995) reported selective weed removal produces a channel that can be self-cleaning of weeds and sediment, have unimpeded water flow, and greater diversity in habitat for aquatic biota.

Manipulating channel shape (King 1996) and vegetation (Pitlo & Dawson 1990) have been shown to improve the hydraulic efficiency of waterways, while Petersen et al. (1992) have tested the benefits of side slope reductions for water quality and reduced frequency of bank failures and channel maintenance. However, the ecological benefits of these channel enhancements have not been rigorously quantified, and it is difficult to generalise the effectiveness of the vegetation and channel shape changes.

5.5 RIPARIAN MANAGEMENT

Several reviews and guidelines now exist on the role of riparian vegetation in New Zealand (Collier et al. 1995; ORC 1996; Heatley 1998; MfE 2000). Benefits of riparian planting include:

- Provision of habitat and food for terrestrial and aquatic species
- Improved light, temperature, nutrient and sediment regimes
- Channel and bank stability
- Shading for aquatic plant control

Riparian fencing and planting are probably the most effective activities that can be undertaken to reduce sediment and contaminate runoff into farm drains. Riparian planting has been shown to reduce bank erosion by up to 50% compared to unplanted banks (Heatley 1998). However, riparian fencing and planting is not a panacea—these practices may reduce contamination, but they do not address or mitigate land management problems. For example, the effectiveness of buffer strips and other control measures are highly dependent on the source, volume, and type of contaminant, as well as the specific local conditions (e.g. EPA 1993; NCSU 1995; EPA 2000). If used incorrectly, riparian planting can cause further problems (e.g. planting willows can increase bank instability because of wind throw—Thorne 1990; Crabbe, eastern Bay of Plenty, pers. comm.). Furthermore, the type and height of vegetation required for shade is dependent on the width and the cross-section of the drain (Dawson 1978; Williamson et al. 1990). Crabbe (1994) and Christchurch City Council (1996) recommend tree species that might be appropriate for riparian planting (Table 5).

Figure 7. Aquatic macrophytes have been selectively removed to create a meandering low-flow channel, with retention of some in-stream habitat.

Riparian planting frequently provides natural shading which can limit the growth of aquatic weeds (Dawson & Kern-Hansen 1978; Crabbe 1994; Young et al. 2000), however, it may be difficult to reduce light to a level which will limit the growth of pest weeds (Rutherford et al. 1997). In an 8-month trial in a small drain in the Waikato, Scarsbrook et al. (2000) reduced light levels by 90% with artificial shading. In this study there was no effect on the overall amount of plant cover that occurred across the stream, however, there was a significant change in both the type and density of plants growing under the shade. During the summer months shading dramatically

TABLE 5. SPECIES THAT MAY BE APPROPRIATE AS DRAIN SHADE TRESS (Crabbe 1994).

SCIENTIFIC NAME	COMMON NAME
Pittosporum eugenioides	Lemonwood
P. crasssifolium	Karo
P. tenuifolium	Kohuhu
Coprosma repens	Taupata
C. robusta	Karamu
Griselinia littoralis	Broadleaf
Leptospermum ericoides	Kanuka
L. scoparium	Manuka
Sophora tetraptera	Kowhai
Dodonaea viscosa	Green akeake
D. purpurea	Purple akeake
Metrosideros excelsa	Pohutukawa
Corynocarpus laevigatus	Karaka
Dacrycarpus dacrydioides	Kahikatea
Podocarpus totara	Totara
Agathis australis	Kauri
Vitex lucens	Puriri
Alnus glutinosa	Alder

reduced the growth of the dominant aquatic plant *Polygonum*, and plant biomass was only 20% of that in an unshaded 'control' reach. The shaded reach also supported a more diverse plant community with several native species being co-dominant (particularly *Potamogeton* and *Nitella*), in contrast the unshaded control was almost entirely dominated by *Polygonum*. Surveys of natural shading by riparian trees have shown significant effects on aquatic plants. Young et al. (2000) found that riparian shading reduced light levels to < 200 mmol/m^2/s. *Lagarosiphon*, willow weed and watercress were significantly reduced, while the native *Nitella* was unaffected by low light levels. Crabbe (1994) surveyed drains throughout the Bay of Plenty and concluded that natural shading could be used to control aquatic weeds in many small drains (1–2 m wide).

5.6 TILE DRAINS

The role of sub-surface drains (e.g. tile drains) as sources of sediments and nutrients has been documented in Europe (Petersen et al. 1992), the United States (EPA 1993), and New Zealand (Nguyen et al. 1998). The construction of mini-wetlands at the exit of tile drains and within waterways has been advocated for control of sub-surface contaminants by Petersen et al. (1992), however, no research has been undertaken in New Zealand to assess either the effectiveness or longevity of wetlands in stripping sub-surface contaminants entering drains (Nguyen et al. 1998).

5.7 DRAIN NATURALISATION

Artificial drains are frequently engineered as straight, narrow and deep channels, but the natural tendency of a lowland stream is to meander, widen and shallow. Consequently, in engineered channels, bank erosion occurs unless there is heavy riparian vegetation, the drain is formed of erosion resistant material (e.g. cohesive soils), or the channel banks are protected (e.g. grade control structures and rip rap). Several overseas reviews have indicated that more cost-effective and sustainable management can be achieved by naturalising the waterway (e.g. Brookes & Shields 1996; Andersen & Svendsen 1997; FISRWG 1999). If left alone, channelised reaches will frequently return to their natural shape (Brookes 1992). A more interventionist and costly approach is to restore natural features in rivers and streams. The Wandse Stream in Germany is one of the first well-documented examples of a stream that was deliberately re-established in a meandering pattern in 1982 (Purseglove 1988). While in Denmark, three years following re-meandering of 580 m of the Idom Å Stream significant increases in the trout population were observed (DEPA 1995). In the re-meandered reach, trout populations had recovered to the levels observed in a natural reach downstream. Stream restoration is still very much in its infancy with much to be learned from basic research and monitoring of the success or failure of projects (Brookes 1996).

The creation of a natural stream shape has rarely been attempted in New Zealand. Environment Southland have trialled a constructed sinuous pattern following natural depressions in Pourahiri Stream, and it is hoped a more natural cross section will develop if the reach is not over maintained. A two-stage channel based on a meandering reference stream has been adopted in the 3 km diversion of the channelised Waikaka River, Southland, however, no data is available on its effectiveness (Hudson 1999).

5.8 VEGETATION CONTROL

Aquatic and riparian vegetation management is a major component of drainage maintenance. Although the focus of maintenance activities is initially the control of weeds, in reality vegetation control becomes a much broader activity. From a drain-efficiency perspective in-stream vegetation often plays an important role in limiting erosion. In addition, in-stream and riparian vegetation provide several environmental benefits (e.g. increased habitat and nutrient filtration). Therefore, effective vegetation management should include careful planning, preparation, and practices to maximise beneficial vegetation growth (e.g. erosion control and habitat), and at the same time minimise potential adverse effects of vegetation in drains (i.e. flow impedance) (ASCE 1991). Successful control of macrophytes is largely dependent on incorporating three key components into a management programme (De Waal et al. 1995):

- Using the knowledge of the auto ecology of the particular species (i.e. understanding the whole life cycle, and requirements of the species) to determine control measures
- Developing a coordinated management programme
- Stopping further spread

Successful vegetation management requires correct taxonomic identification of the problem plants. This enables the selection of appropriate management measures, which vary widely between plants. For example, to control *Fallopia japonica* (Japanese knotweed) it is important to contain and eliminate the large underground rhizome system (De Waal et al. 1995). While the giant hogweed *Heracleum mantegazzianum* has two regeneration strategies; the formation of an over-wintering tap root and the production of a large amount of seeds developing into a persistent seed bank. For lasting control it is necessary to prevent seed dispersal by controlling plants before flowering (De Waal et al. 1995).

Management measures to prevent weed problems include:

- Controlling upstream sources of weeds (i.e. even if there is no persistent local seed bank, re-invasion may occur with seeds from upstream)
- Limiting the spread of weeds (e.g. cleaning excavators to stop transfer of weeds between drains; control disposal of spoil)
- Maintaining desirable plant species which can compete with the weeds
- Enhancing channels to indirectly control weeds by modifying the light, hydraulic and in-stream sediment-nutrient regimes

6. Knowledge gaps

Our review of existing literature indicates that there are a number gaps in our understanding of the effects of current drain management activities in New Zealand. We have identified some of the key ones here. Specifically, these fall into two broad categories.

6.1 UNDERSTANDING DRAIN HYDROLOGY

There is little or no documented evidence of the effects of either mechanical digging, or weed clearing on the hydraulics of drains (i.e. of their capacity and efficiency at different flow levels) or of the effects on the water table of the surrounding land. The lack of data on these topics is surprising, considering the effort put into these activities. Without understanding how efficient these practices actually are, it is very difficult to develop and promote improved practices.

6.2 MANAGEMENT OF SEDIMENT, NUTRIENTS, AND MACROPHYTES

Some overseas studies indicate that physical removal of macrophytes affect fish communities, however, there has not been any rigorous testing of this in New Zealand. Studies by McDowall & Lambert (1996), Ryder (1997), and Goldsmith (2000) indicate that there may be significant impacts, but their results were confounded by problems with the study design.

Limited overseas research suggests 'selective' weed cutting may be an effective management tool, but there is little quantitative evidence. Anecdotal evidence indicates that aquatic plants significantly increase sediment retention, and promote deposition in drains, it is likely that selective weed-cutting patterns can maintain a weed free and silt free channel. Trials in Okeover Stream (University of Canterbury) indicate this is possible.

Little work has been done on promising alternative strategies to reduce sediment and nutrient transport in drains (e.g. creating sediment 'traps', or sediment-contaminant retention 'wetlands'). The literature suggests there is great potential for using flushing flows to remove sediment in some drains.

Chemical sprays, and low dissolved oxygen (DO) associated with weed decomposition, probably affect drain communities in New Zealand, but this has not been studied. McDowall & Lambert (1996) suggest that as a possibility, while unpublished laboratory experiments at the University of Canterbury indicate that macrophytes can reduce DO to critical levels for native fish. However, there does not seem to be any study that has adequately addressed this issue.

7. Recommendations

While there is much still to learn about drain management in New Zealand, there are several actions that can be taken to improve our understanding and management of these systems.

- As a result of this review and from responses to the council survey we conclude that no one form of drainage management will apply to all situations. Different drain management practices should be used for different locations (e.g. coastal drains v. inland drains), and different types of drain (e.g. ephemeral v. permanent flow, drains with different substrate type, riparian vegetation, and land management). We recommend that a classification system for drains needs to be developed. By being able to classify a drain councils will be able to adopt specific management practices for different values and conditions specific to particular types of drains.
- This review has identified several alternative drain maintenance practices, which have been reported overseas. Trials of the efficiency and applicability of these practices need to be conducted in New Zealand. We recommend that comparative trials of partial drain clearing (e.g. clearing only one bank of weeds or creating meandering channels), drain naturalisation, and use of sediment traps and wetlands be conducted, and these trials be compared to current management practices in order to determine their relative efficiencies.
- The efficiency of performance based approaches to drain management need to be compared to process based approaches. A comparison of these approaches will improve our understanding of these systems and enable councils to manage flood waters and aquatic weed levels.

- All councils should have in place recommended practices for sediment and contaminant control. These should include control of livestock access to watercourses, use of vegetated riparian zones, use of riparian plantings for shade control of weeds and bank stabilisation, and the use of sediment traps to reduce sedimentation within the waterway. Practice guidelines should be developed and rigorously evaluated for New Zealand conditions.

8. Acknowledgements

This project was funded by Department of Conservation (investigation no. 3384), Ministry for the Environment, and the Ministry for Agriculture & Forestry. Lindsay Chadderton, Rosemary Miller, and Murray Neilson (Department of Conservation) highlighted this issue. We thank Lindsay Chadderton, Neil Deans, Roger Young and two anonymous referees for comments on a draft of the manuscript. Support and advice on current practices and operations were provided by Noel Hinton and others at Environment Southland, Bruce Crabbe (Environment Bay of Plenty), Norm Olsen (Hawkes Bay Regional Council), and John Phillips (Horizons mw). We thank staff at councils throughout the country for their responses to the survey.

9. References

Alberta Agriculture 1998: Biological weed control in Alberta using triploid grass carp. Agdex 485/641-1. Alberta Agriculture, Edmonton.

ASAE 1994: Design, installation and operation of water table management systems for subirrigation/controlled drainage in humid areas. Pp. 650–660 in ASAE standards, engineering practices and data. 41st edtn. American Society of Agricultural Engineers, St. Joseph, Michigan.

ASCE 1991: Management, operation and maintenance of irrigation and drainage systems. *ASCE Manuals and Reports on Engineering Practice No. 57*. American Society of Civil Engineers, New York.

Andersen, H.E.; Svendsen, L.M. 1997: Suspended sediment and total phosphorus transport in a major Danish river: methods and estimation of the effects of a coming major restoration. *Aquatic conservation : marine and freshwater ecosystems* 7: 265–276.

Bay of Plenty 2000: Operational procedures manual—drainage control. A requirement of resource consent numbers 02 4857 and 02 4963. Operations and Rural Services Department, Environment Bay of Plenty, Tauranga.

Benstead, P.; Drake, M.; Jos, P.; Mountford, O.; Newbold, C.; Treweek, J. 1997: The wet grassland guide. Managing floodplain and coastal wet grasslands for wildlife. Summerfield Books, Cumbria. 245 p.

Biggs, B.J. 2000: New Zealand periphyton guideline: detecting, monitoring and managing enrichment in streams. Ministry for the Environment, Wellington.

Biggs, B.J; Price, G.M. 1987: A survey of filamentous algal proliferations in New Zealand rivers. *New Zealand Journal of Marine and Freshwater Research 21*: 175–191.

Brookes, A. 1988: Channelized rivers: perspectives for environmental management. John Wiley & Sons, Chichester.

Brookes, A. 1989: Alternative channelisation procedures. Pp. 139–162 in Gore, J.A.; Petts, G.E. (Eds) Alternatives in regulated river management. CRC Press, Boca Raton, Florida.

Brookes, A. 1992: Recovery and restoration of some engineered British river channels. Pp. 337–352 in Boon, P.J.; Calow, P.; Petts, G.E. (Eds) River conservation and management. John Wiley, Chichester.

Brookes, A. 1996: River restoration experience in northern Europe. Pp. 233–267 in Brookes, A.; Shields, F.D. Jr. (Eds) River channel restoration. John Wiley, Chichester.

Brookes, A; Shields, F.D. 1996: Towards an approach to sustainable river restoration. Pp 385–402 in Brookes, A.; Shields, F.D. Jr. (Eds) River channel restoration. John Wiley, Chichester.

Burnet, A.M. 1972: Effects of paraquat on invertebrates in a Canterbury stream, New Zealand. *New Zealand Journal of Marine and Freshwater Research 6 (4)*: 448–455.

Cadwallader, P.L. 1975: Distribution and ecology of the Canterbury Mudfish, *Neochanna burrowsius* (Phillipps)(Salmoniformes: Galaxiidae). *Journal of the Royal Society of New Zealand 5(1)*: 21–30.

Christchurch City Council 1996: Stream planting guide. Guidelines for native planting alongside streams in Christchurch. Waterway Enhancement Programme, Water Services Unit. Christchurch City Council, Christchurch, N.Z.

Clayton, J.S.; Champion, P.D.; McCarter, N.H. 1995: Control of *Hydrilla verticillata* in a New Zealand lake using triploid grass carp. Pp. 275–285 in Delfosse, E.S.; Scott, R.R. (Eds) Proceedings of the 8th International Symposium on Biological Control of Weeds. DSIR/ CSIRO Melbourne.

Close, M.E.; Davies-Colley, R.J. 1990a: Baseflow water chemistry in New Zealand rivers. 1. Characterisation. *New Zealand Journal of Marine and Freshwater Research 24*: 319–342.

Close, M.E.; Davies-Colley, R.J. 1990b: Baseflow water chemistry in New Zealand rivers. 2. Influence of environmental factors. *New Zealand Journal of Marine and Freshwater Research 24*: 343–356.

Collier, K.J.; Cooper, A.B.; Davies-Colley, R.J.; Rutherford, J.C.; Smith, C.M.; Williamson, R.B. 1995: Managing riparian zones: a contribution to protecting New Zealand's rivers and streams. Department of Conservation, Wellington. 2 vols.

Cooke, G.D.; Welch, B.; Peterson, S.A.; Newroth, P.R. 1993: Restoration and management of lakes and reservoirs. Lewis Publishers, Chelsea, MI.

Cordone, A.J.; Kelley, D.W. 1961: The influences of inorganic sediment on the aquatic life of streams. *California Fish and Game 47*: 189–228.

Crabbe, B. 1994: Shade tree investigation: An alternative method of aquatic weed management. *Environment Bay of Plenty Operations Report 94/1, July 1994*. Environment Bay of Plenty, Whakatane.

Crabbe, B.; Ngapo, N. 2000: Draft environmental code of practice for rivers and drainage activities. *Environment Bay of Plenty Operations Report 20001/01*. Environment Bay of Plenty, Whakatane. 78 p.

Dawson, F.H. 1978: Aquatic plant management in semi-natural streams: the role of marginal vegetation. *Journal of Environmental Management 6*: 213–221.

Dawson, F.H.; Kern-Hansen, U. 1978: Aquatic weed management in natural streams: the effect of shade by the marginal vegetation. *Verhandungen der internationalen Vereinigung fur theoretische und angewandte Limnologie 20*: 1451–1456.

DEPA 1995: Rehabilitating Danish streams. Danish Environmental Protection Agency. Milj-Tema No. 11.

De Waal, L.C.; Child, L.E; Wade, M. 1995: The management of three alien invasive plants. Pp. 315–321 in Harper, D.M.; Ferguson, A.J.D. (Eds) The ecological basis for river management. John Wiley, Chichester.

Dunderdale, J.A.L.; Morris, J. 1996: The economics of aquatic vegetation removal in rivers and land drainage systems. *Hydrobiologia 340*: 157–161.

Edwards, D.J.; Moore, E. 1975: Control of water weeds by grass carp in a drainage ditch in New Zealand. *New Zealand Journal of Marine and Freshwater Research 9(3)*: 282–292.

Environment Waikato 1998: Waikato state of the environment report 1998. Environment Waikato, Hamilton, N.Z.

Environment Waikato 2000: Draft asset management plan land drainage. Environment Waikato Land Drainage, Hamilton, N.Z.

EPA 1986: Guidance for re-registration of pesticide products containing as the active ingredient diquat dibromide (032201). U.S. Environmental Protection Agency. Office of Pesticide Programs, Washington, DC.

EPA 1987: Health Advisory: Glyphosate. United States Environmental Protection Agency, Office of Drinking Water, Washington, DC.

EPA 1992: Pesticide tolerance for glyphosate. Federal Registry. 57: 8739 40, 1992.

EPA 1993: Guidance specifying management measures for sources of non-point pollution in coastal waters. United States Environmental Protection Agency, EPA-840-B-92-002. Washington, DC.

EPA 2000: National management measures to control non-point source pollution from agriculture. Draft. United States Environmental Protection Agency, Washington DC.

FISRWG 1999: Stream corridor restoration—principles, processes, and practices. Federal Interagency Stream Restoration Working Group, National Technical Information Service, Springfield, VA.

Gillett, J.W. 1970: The biological impact of pesticides in the environment. *Environmental Health Sciences Series No. 1*. Oregon State University, Corvallis, OR.

Goldsmith, R.J. 2000: The response of fish populations in Southland streams to the disturbance of macrophyte removal. *University of Otago Wildlife Management Report No. 119*.

Harding, J.S.; Winterbourn, M.J. 1995: Effects of contrasting land use on physico-chemical conditions and benthic assemblages of streams in a Canterbury (South Island, New Zealand) river system. *New Zealand Journal of Marine and Freshwater Research 29*: 479–492.

Haynes, R.J. 1995: Soil structural breakdown and compaction in New Zealand soils. *MAF Policy Technical Paper*. Ministry of Agriculture, Wellington.

Heatley, P.R. 1998: Dairying and the environment: Farm management issues. Dairying and the Environment Committee, Palmerston North.

Hicks, D.L. 1995: Control of soil erosion on farmland: a summary of erosion's impact on New Zealand agriculture, and farm management practices which counteract it. *MAF Policy Technical Paper 95/4*. Ministry of Agriculture, Wellington.

Howard, P.H., Ed. 1991: Handbook of environmental fate and exposure data for organic chemicals. Vol. III: Pesticides. Lewis Publishers, Chelsea, MI.

Hudson, H.R. 1998a: Sustainable drainage management strategy: revision and further development of best management practices. *Environmental Management Associates Report 98-23*. Environmental Management Associates, Christchurch. 26 p.

Hudson, H.R. 1998b: A review of sustainable drainage management concepts and practices. *Environmental Management Associates Report 98-09*. Environmental Management Associates, Christchurch. 45 p.

Hudson, H.R. 1999: Waikaka River diversion: issues and options. *Environmental Management Associates Report 99-18*. Environmental Management Associates, Christchurch. 24 p.

Hughes, H.R. 1984: An environmental view of land drainage. Proceedings of the 2nd National Land Drainage Seminar, Massey University, Palmerston North.

James, T.I.; Harding, J.S.; Lattimore, S.A. 1999: The state of the West Coast surface water quality. Volume 1: Summary, methods, discussion, and recommendations. West Coast Regional Council, Greymouth.

Johnson, W.W.; Finley, M.T. 1980: Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. *Resource Publications 137*. Fish and Wildlife Service, US Department of the Interior, Washington, DC.

Kern-Hansen, U. 1978: The drift of *Gammarus pulex* I. In relation to macrophyte cutting in four small Danish lowland streams. *Verhandungen der internationalen Vereinigung fur theoretische und angewandte Limnologie 20*: 1440–1445.

Kidd, H.; James, D.R. (Eds) 1991: The agrochemicals handbook. 3rd edtn. Royal Society of Chemistry Information Services, Cambridge, UK.

King, J.J. 1996: The impact of drainage maintenance strategies on the flora of a low gradient, drained Irish salmonid river. *Hydrobiologia 340*: 197–203.

Lalonde, V.; Hughes-Games, G. 1997: B.C. agricultural drainage manual. British Columbia, Ministry of Agriculture, Fisheries and Food, Victoria, BC. 271 p.

Ludlow, J. 1995: Management of aquatic plant communities in Rodman Reservoir from 1969–1994. *Aquatics 17(3)*: 11–15.

Madsen, B.L. 1995: The riverkeeper's field book. Danish Environmental Protection Agency, Copenhagen. 56 p.

Madsen, J.D. 1997: Methods for management of non-indigenous aquatic plants. Pp. 145–171 in Luken, J.O; Thieret, J.W, (Eds) Assessment and management of plant invasions. Springer, New York.

Madsen, J.D. 2000: Advantages and disadvantages of aquatic plant management techniques. *LakeLine 20(1)*: 22–34.

Malik, J.; Barry, G.; Kishore, G. 1989: The herbicide glyphosate. *BioFactors. 2(1)*: 17–25.

Marshall, J.W. 1978: An experimental study of benthic algal standing crops in the Leeston drain, Canterbury. *Mauri Ora 6*: 33–19.

Marshall, J.W.; Winterbourn, M.J. 1979: An ecological study of a small New Zealand stream with particular reference to the Oligochaeta. *Hydrobiologia 63*: 199–208.

McDowall, R.M. 1990: New Zealand freshwater fishes: a natural history and guide. Heinemann Reed & MAF Publishing Group, Auckland.

McDowall, R.M.; Lambert, P. 1996: Fish and fisheries values of the lower Mataura River: an assessment of values and implications of effluent discharges to the river. Consultancy report No. COO605/1. National Institute of Water and Atmospheric Research, Christchurch.

MfE 1992: Water quality guidelines No. 1. Guidelines for the control of undesirable biological growths in water. Ministry for the Environment, Wellington. 60 p.

MfE 1997: Reducing the impacts of agricultural runoff on water quality: a discussion of policy approaches. Ministry for the Environment, Wellington. 44 p.

MfE 2000: Managing waterways in farms—draft. Ministry for the Environment, Wellington.

Mitchell, C.P. 1990: Whitebait spawning ground management: interim report. *New Zealand Freshwater Fisheries Report No. 131*. Freshwater Fisheries Centre, MAF Fisheries, Christchurch. 20 p.

Monsanto 1985: Toxicology of glyphosate and roundup herbicide. Monsanto Company, St. Louis, MO.

NCSU 1995: Watersheds. Best management practices for non-point source pollution control. North Carolina State University Extension, Raleigh, NC.

Newbold, C.; Honner, J.; Buckley, K. 1989: Nature conservation and the management of drainage channels. Nature Conservancy Council, Association of Drainage Authorities. Peterborough, UK. 108 p.

Newton, B.; Pringle, C.; Bjorkland, R. 1999: Stream visual assessment protocol. *National Water and Climate Center Technical Note 99-1*. US Department of Agriculture, Washington, DC. 35 p.

Nguyen, M.L.; Monaghan, R.; Tanner, C.C. 1998: Zeolites and constructed wetlands: possible technologies for nutrient recapture and drainage pollution control. Proceedings 11th Fertiliser and Lime Research Centre Annual Workshop, 11–12 February 1998, Massey University, Palmerston North.

NLM 1995: Hazardous substances databank. United States National Library of Medicine, Bethesda, MD.

NRCS 1990: Controlled drainage. Conservation Practice Standard 335. Natural Resources Conservation Service, US Department of Agriculture, Washington, DC.

Olsen, N.; Hansen, G.; Adye, M. 2000: Heretaunga Plains flood control scheme. Part 2: drainage and pumping. Hawke's Bay Regional Council. Napier. 87 p.

ORC 1996: Riparian management. Otago Regional Council, Dunedin.

Pearson, R.G.; Jones, N.V. 1978: The effects of weed-cutting on the macro-invertebrate fauna of a canalised section of the River Hull, a Northern English chalk stream. *Journal of Environmental Management 7*: 91–91.

Peirce, J.R. 1998: Declared plant control. Agriculture Western Australia, *Miscellaneous Publication 4/98*.

Petersen, R.C.; Petersen, L.B.; Lacoursire, J. 1992: A building-block model for stream restoration. Pp. 293–309 in Boon, P.J.; Calow, P.; Petts, G.E. (Eds) River conservation and management. John Wiley, Chichester.

Pitlo, R.H.; Dawson, F.H. 1990: Flow-resistance of aquatic weeds. Pp. 74–84 in Pieterse, A.H.; Murphy, K.J. (Eds) Aquatic weeds: the ecology and management of nuisance aquatic vegetation. University Press, Oxford.

Pimentel, D. 1971: Ecological effects of pesticides on nontarget species. Executive Office of the President's Office of Science and Technology, Washington, DC.

Platts W.S.; Megahan W.F.; Minshall G.W. 1983: Methods for evaluating stream, riparian, and biotic conditions. US Department of Agriculture General Technical Report INT-138. 70 p.

Plafkin, J.L.; Barbour, M.T.; Porter, K.D.; Gross, S.K.; Hughes, R.T. 1989: Rapid bioassessment protocols for use in stream and rivers: benthic macroinvertebrates and fish. US Environmental Protection Agency EPA/440/4/89/001. Washington, DC.

Purseglove, J. 1998: Taming the flood. A history and natural history of rivers and wetlands. Oxford University Press, New York.

Quinn, J.M.; Cooper, A.B.; Davies-Colley, R.J.; Rutherford, J.C.; Williamson, R.B. 1997: Land-use effects on habitat, water quality, periphyton, and benthic invertebrates in Waikato, New Zealand, hill-country streams. *New Zealand Journal of Marine and Freshwater Research 31*: 579–598.

Roper-Lindsay, J. 1991: An environmental assessment of river engineering operations in Canterbury region. Boffa Miskell Partners report to Canterbury Regional Council, Christchurch, N.Z.

Rowe, D.K.; Schipper, C.M. 1985: An assessment of the impact of grass carp (*Ctenoparyngodon idella*) in New Zealand waters. *Fisheries Environmental Report No. 58*.

Rutherford, J.C.; Davies-Colley, R.J.; Quinn, J.M.; Stroud, M.J.; Cooper, A.B. 1997: Stream, shade: towards a restoration strategy. NIWA, Hamilton, and Department of Conservation, Wellington. 161 p.

Ryan, P.A. 1991: Environmental effects of sediment on New Zealand streams: a review. *New Zealand Journal of Marine and Freshwater Research 25*: 207–221.

Ryder, G. 1997: Effects of drain clearing on aquatic biota. Report for Southland Regional Council. Ryder Consulting, Dunedin.

Scarsbrook, M.R.; Wilcock, R.; Costley, K.; Nagels, J. 2000: Effects of shading on aquatic plants, invertebrates and water quality in Toenepi Stream. Client report DRI00207. National Institute of Water and Atmospheric Research, Hamilton, N.Z.

Simonin, H.A.; Skea J.C. 1977: Toxicity of diquat and cutrine to fingerling brown trout. *New York Fish and Game Journal 24(1)*: 37 45.

Siver, P.A.; Coleman, A.M.; Benson, G.A.; Simpson, J.T. 1986: The effects of winter drawdown on macrophytes in Candlewood Lake, Connecticut. *Lake and Reservoir Management 2*: 69–73.

Skrzynski, W. 1968: The Canterbury Mudfish, Galaxias burrowsius Phillipps, a vanishing species. *New Zealand Journal of Marine and Freshwater Research 2*: 688–697.

Tarver, D.P. 1980: Water fluctuation and the aquatic flora of Lake Miccosukee. *Journal of Aquatic Plant Management 18*: 19–23.

Tasman District Council 2000: Environment today! Tasman District Council, Richmond, N.Z.

Thoreson, B.P.; Slack, D.C.; Satyal, R.P.; Neupane, R.S.S. 1997: Performance-based maintenance for irrigation systems. *Journal of Irrigation and Drainage Engineering. 123 (2)*: 100–105.

Thorne, C.R. 1990: Effects of vegetation on riverbank erosion and stability. In Thornes, J.B. (Ed.) Vegetation and erosion. John Wiley, Chichester.

Tucker, B.V. 1980: Diquat environmental chemistry. Ortho Agricultural Division, Chevron Chemical Corporation, Richmond, VA.

Wade, P.M. 1994: Management of macrophytic vegetation. Pp. 363–385 in Calow, P.; Petts, G.E. (Eds) The rivers handbook. Vol. 2. Blackwell Scientific, Oxford.

Wade, P.M. 1995: The management of riverine vegetation. Pp. 307–313 in Harper, D.M.; Ferguson, A.J.D. (Eds) The ecological basis of river management. John Wiley, Chichester.

Waters, T.F. 1995: Sediment in stream: sources, biological effects, and control. *American Fisheries Society Monograph 7*. American Fisheries Society, Bethesda, MD.

Wauchope, R.D.; Buttler, T.M.; Hornsby, A.G.; Augustijn Beckers, P.W.M.; Burt, J.P. 1992: SCS/ARS/CES Pesticide properties database for environmental decision making. *Review Environmental Contaminant Toxicology 123*: 1–157.

Wells, R.D.; Hicks, B.J.; Bannon, H.J.; Dyer, J.; Teal, P. 2000: Impacts of grass carp on the biota of Churchill East drain. Unpublished *NIWA Client report DOC00231*. National Institute of Water and Atmospheric Research, Hamilton, N.Z. 53 p.

Wilcock, R.J.; Rodda, H.J.; Scarsbrook, M.R.; Cooper, A.B.; Stroud, M.J.; Nagels, J.W.; Thorrold, B.S.; O'Connor, M.B.; Singleton P.L. 1998: The influence of dairying on the freshwater environment (The Toenepi Study). Volume 2. *NIWA Client report DRI60202*. National Institute of Water and Atmospheric Research, Hamilton, N.Z.

Williamson, R.B.; Smith, R.K.; Quinn, J.M. 1990: The effects of riparian protection on stream form and stability of 6 grazed streams, Southland, New Zealand. *Water Quality Centre Publication No. 19*. DSIR, Hamilton, N.Z. 42 p.

Williman, E.B.; Bezar, S.B. 1999: Drainage Report 1998–1999. Marlborough District Council, Blenheim. 5 p.

Wood, P.J.; Armitage, P.D. 1997: Biological effects of fine sediment in the lotic environment. *Environmental Management 21(2)*: 203–217.

WSDE 2000: Technical information about *Hydrilla verticillata*. Washington State Department of Ecology, Olympia, WA.

WSSA 1994: Herbicide Handbook, Seventh Edition. Weed Science Soc. of America, Champaign, IL.

Young, R.; Strickland, R.; Harding, J.; Stark, J.; Hayes, J. 2000: The ecology of Spring Creek. *Cawthron Report No. 611*. Cawthron Institute, Nelson, N.Z. 52 p.

Appendix 1

SUMMARY OF COUNCIL RESPONSES TO THE CAWTHRON INSTITUTE SURVEY

(On following pages)

SUMMARY OF COUNCIL RESPONSES TO THE CAWTHRON INSTITUTE SURVEY

DISTRICT OR REGION	CoP*	EXCAV-ATOR	HAND	SPRAYING	CHEMICAL	OTHER	AVERAGE FREQUENCY	PERIOD	AVERAGE BUDGET
Banks Peninsula DC	No	Mostly	Rarely	Sometimes	Roundup		1 × /year		$8 500
Bay of Plenty	Yes	Sometimes	Rarely	Mostly (2nd choice)	Roundup, rare use of diquat	Weed cutter boat 1st choice	>2 × /year	As required	$500 000
Buller DC	No	Mostly	Rarely	Sometimes	Roundup		1 × /year	As required	$15 000
Environment Southland	In prep.	Mostly		Sometimes	Roundup, Diquat		1–3–5 year cycle	Pred. Mar & Oct	$520 000
Grey DC		Rarely	Mostly	Rarely	Roundup		2 × /year	Spring, Autumn	$42 000
Hastings DC	Spec.	Rarely	Rarely	Sometimes	Roundup	Mowing	3 × /year	Sep, Dec, Apr	$95 000
Horizons.mw Manawatu–Wanganui	In prep.	Sometimes	Sometimes	Mostly	Roundup		2 × /year	Continuous	$200 000
Horowhenua DC	No	Sometimes	Rarely	Mostly	Roundup, Escort		2 × /year	Spring, Autumn	
Hurunui DC	No	Mostly		Rarely	Roundup		Some 2 –3 year cycle		$15 000
Kaipara DC	No	Sometimes	Rarely	Mostly	Roundup. Gallant		1 × / year	Autumn	$400 000
Kawerau DC	No	Mostly	Sometimes		Roundup		1 × /year	Mar	$5000
Marlborough DC	Yes	Sometimes	Sometimes	Mostly	Roundup, occasion-ally Torpedo	Weed cutting	2 × year spray,	Excavator on demand	$120 000
Nelson City Council	No	Sometimes	Sometimes	Sometimes	Roundup		1 × /year	Mar, Apr	$150 000
Northland RC		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Opotiki DC	Spec.	Mostly	Rarely	Sometimes	Roundup		1 × /year	Summer	$30 000
Otago RC	No	Sometimes	Sometimes	Mostly	Roundup	Mowing	Spray 1 × /year Excav. c.5 year cycle	Nov, Apr	$350 000
Otorohanga DC	No	Sometimes		Mostly	Roundup, Torpedo		As required	As required	$50 000

(Continued next page)

DISTRICT OR REGION	CoP*	EXCAVATOR	HAND	SPRAYING	CHEMICAL	OTHER	AVERAGE FREQUENCY	PERIOD	AVERAGE BUDGET
Queenstown Lakes DC	No	Sometimes	Rarely	Sometimes	Roundup		As required	As required	
Rodney DC	No	Sometimes	Rarely	Sometimes	Roundup, Escort		1 × /year	Apr–Jun	$200 000
South Wairarapa DC	No				Roundup + Escort, simazine		1 × /year		$190 000
Southland DC	No	Sometimes	Sometimes	Sometimes	Roundup		As required	As required	
Stratford DC		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tararua DC	No	Sometimes	Sometimes	Mostly	Roundup G2		2 × /year	Nov–Dec, Apr–May	
Tasman DC	No			Mostly			As required		
Tauranga DC	No	Sometimes	Rarely	Mostly	Roundup		Spray 2 × /year Excav. 3 year cycle	Oct, Feb	$88 000
Timaru DC	No	Sometimes	Sometimes	Rarely			As required	As required	$7500
Waimakariri DC	No	Mostly	Mostly	Mostly	Roundup, Diquat, Triclopyr all with Pulse or Boost		As required	Pred. Jan, Feb, Mar	$263 000
Waimate DC	No	Mostly		Sometimes	Roundup		As required	As required	$100 00
Waitaki DC	Spec.	Mostly	Rarely	Sometimes	Roundup		3 or 5 year cycle	Winter, spring	$90 000
Waipa DC	Yes	Mostly		Mostly	Roundup		2 × /year	Autumn, spring	$80 000
Waitomo DC	No	Rarely					On demand	On demand	$7000
Wellington RC	No	Sometimes	At pump stations	Mostly	Roundup		As required, 1 × to 2 × /year	Dec, Apr, May	$70 000
West Coast RC	No	Mostly		Sometimes	Roundup		As required	As required	$10 000

* CoP = Code of Practice. Refers to an environmental code. 'Spec.' refers to use of a contract or maintenance specification.
n.a. = not available.