STATE OF SURFACE WATER QUALITY IN TASMAN DISTRICT

Document Status: Final Report

June 2005

A technical report presenting results of the Tasman District Council's "State of the Environment" Surface Water Quality Monitoring Programme from 1999 to April 2004 incorporating monitoring data collected by National Water Quality Network from 1989 to 2003 and other data. Along with physical and chemical indicators, results from macroinvertebrate and periphyton indicators are presented. The report highlights freshwater quality issues and outlines what Tasman District Council is doing to help improve water quality where it is found to be poor.

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Cover Photos: From Top: Matakitaki River at Nardoo, Motupipi River at Factory Farm Crossing, Kaituna River at Sollys.

Tasman District Council Ref: R05007
Cawthron Report No. 933

ISBN: 0-473-10060-6

File ref: G:\Environmental\Trevor James\Surface Water Quality\Reports\SER 2005\SWQ SER June2005 - Final Draft1.doc

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EXECUTIVE SUMMARY

As part of its obligations under the Resource Management Act, Tasman District Council monitors the state of surface water quality and river health at selected sites throughout the Tasman District. Data from this monitoring programme and selected information collected as part of scientific studies carried out by other agencies in the District are reviewed in this report.

A range of water quality parameters have been measured at most sites on a quarterly basis at base flow since 1999. Samples of aquatic macroinvertebrates have been collected annually since 1999 at most of the water quality sampling sites. Some types of macroinvertebrates are tolerant to pollution while others are not. Therefore, the presence or absence of particular macroinvertebrate species can indicate the ecological health of a site. The amount and types of periphyton (or algae) growing on the river bed is also indicative of river health and has been measured quarterly at most of the water quality sampling sites since 2001.

A cluster analysis of the water quality results identified three groups of sites. One group consisting of eight small streams had poor water quality. These sites (subsequently labelled as the "red" sites) have poor water clarity and high concentrations of nutrients and faecal indicator bacteria compared with other sites in the District and often exceed water quality guidelines. Dissolved oxygen concentrations were low at times at some of these sites. All of these sites are on small streams draining land that has been intensively developed for agriculture, horticulture, or urban usage. Sites in this group include: Motupipi, Watercress and Winter Creeks (near Takaka), Little Sydney and Waiwhero Creeks (near Motueka), Kikiwa (upper Motueka) and Reservoir Creek in Richmond.

A second group of 11 sites (subsequently labelled as the "yellow" sites) have better water quality than the red sites, but tend to have lower water clarity and higher concentrations of nutrients and faecal bacteria than that in the high quality ("green") sites. The yellow sites include small streams and the downstream end of moderate sized rivers that drain intensively developed areas. Sites in this group include: lower Riwaka, lower Sherry (near Tapawera), Mangles (near Murchison), lower Onekaka (Golden Bay), lower Wai-iti (near Brightwater), Motupiko (upper Motueka catchment), Black Valley (in St Arnaud), and Kaituna (near Collingwood).

The remaining "green" sites had the highest water quality and included forested headwaters and also the downstream reaches of the District's large rivers. Sites in this group include: Motueka, Takaka, Aorere, Buller, Matakitaki, Waimea, Wairoa, Wangapeka.

Sites draining low elevation land had higher concentrations of TN, NO_3-N, NH_4-N, DRP, TP, *E. coli*, and suspended sediments than sites draining hill country, mountains or flowing from a lake. Oxygen saturation was lowest in first order streams. Concentrations of nutrients also tended to be highest in the smaller streams. Concentrations of nutrients, *E. coli* and suspended sediment at sites classified as having pastoral land cover were higher than at sites with indigenous forest or exotic forest land cover. Similarly, water clarity was lower at pastoral sites than in forested sites. The effects of land use on water quality are widely recognised and the results of this analysis are consistent with earlier nationwide studies of water quality patterns.

Continuous water temperature records were available for 23 sites, mostly within the Motueka River catchment. Data from well-shaded headwater streams never exceeded the temperature criteria for protecting ecosystem health during the summer. However, the water temperature criterion was regularly exceeded during summer at sites on small unshaded streams draining developed land (e.g. Waiwhero, Little Sydney, Kikiwa). The temperature criterion was also regularly exceeded in the lower reaches of the Tadmor and Motueka rivers.

Trends in water quality were determined at the three National River Water Quality Network sites (Motueka at Gorge, Motueka at Woodstock, Buller at Longford) where sampling has been conducted monthly since 1989. Concentrations of ammonium nitrogen declined at all three sites over the course of the data record, whereas concentrations of total nitrogen increased at all three sites. Water clarity also tended to increase at all three sites, including the Gorge site, which is upstream of any human land use, over the course of the data record. The fact that these changes were consistent among all three sites suggests that this trend is related to climatic changes, rather than changes in land management. However, nitrate nitrogen concentrations and conductivity increased significantly at the Motueka at Woodstock site over the course of the data record, but not at the other sites, suggesting that these changes may be related to changes in land use within the Motueka Catchment over the last 16 years.

Macroinvertebrate communities indicated good ecosystem health at the majority of the sites that were sampled. However, ecosystem health appears to be poor in many of the small lowland streams that drain the intensively developed parts of the District (e.g. Motupipi River, Watercress Creek, lower Reservoir Creek, Waiwhero, Little Sydney). These sites were also identified as having poor water quality.

Periphyton communities were also indicative of good ecosystem health at the majority of sites. However, again the small lowland streams draining intensively developed land often had excessive accumulations of nuisance algae.

In terms of water quality, the Tasman District is lucky because all of the District's large rivers have a significant proportion of native forest in their catchments. Therefore, any inputs of pollutants from developed land in the middle and lower reaches are substantially diluted by the large volume of high quality water from upstream. The main threats to water quality and stream health in the Tasman District relate to the intensification of agriculture in the District, and to a lesser extent the expansion of residential development in the District. The main problems with water quality in the Tasman District are currently found in small streams which drain intensively developed land. Restoration efforts should focus on reducing nutrient and faecal bacteria inputs to these systems. Efforts should also be made to increase the amount of bank-side vegetation along these streams to provide shading and keep water temperatures below the critical levels required for protecting ecosystem health. If improvements can be made to the water quality of many small streams, this will also lead to cumulative improvements in the quality of water in the main rivers.

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DRP – dissolved reactive phosphorus
Ck - creek
d/s – downstream
E. coli – a faecal indicator bacteria
FSS – fixed (inorganic) suspended solids
ICM – Integrated Catchment Management research programme
MCI – Macroinvertebrate Community Index
NH_4-N – Ammonium nitrogen
NIWA – National Institute of Water & Atmospheric Research
NO_3-N – Nitrate nitrogen
NRWQN – National River Water Quality Network
REC – River Environment Classification
RMA – Resource Management Act
Rv - River
SoE – State of the Environment
SQMCI – Semi-quantitative Macroinvertebrate Community Index
Stm - Stream
SWQMP – Tasman District Council's Surface Water Quality Monitoring Programme
TDC – Tasman District Council
TN – total nitrogen
TP – total phosphorus
TRMP – Tasman Resource Management Plan
TSS – Total suspended solids
u/s – upstream
VSS – volatile (organic) suspended solids

ACKNOWLEDGEMENTS

Tasman District Council and Cawthron would like to thank people and organisations who have assisted in this monitoring programme. In particular we would like to thank landowners who provide access to monitoring sites, National Institute for Water and Atmosphere for data from National Water Quality Network sites, Dinah Grew of TDC for formatting and TDC hydrology department staff who provide field assistance (Martin Doyle, Brenda Clapp, Gordon Curnow, Matt McLarin, Tom Kennedy).

STATEMENT OF DATA VERIFICATION AND LIABILITY

Tasman District Council recognises the importance of good quality data. This first comprehensive surface water quality technical report for the whole District provides interpretation of results from the Tasman District Council Surface Water Quality Monitoring Programme and a summary of relevant information available at time of producing the report.

Data collection and management systems follow systematic quality control procedures (see Tasman District Council Surface Water Quality Monitoring Programme). International Accreditation New Zealand (IANZ) laboratories carried out sample analysis excluding field analysis. Expert staff have been involved in each stage of the monitoring process. A process of internal and external review of this report has been implemented.

While every attempt has been made to ensure the accuracy of the data and information presented, Tasman District Council does not accept any liability for the accuracy of the information. It is the responsibility of the user to ensure the appropriate use of any data or information from the text, tables or figures. Not all available data or information is presented in the report. Only information considered reliable, of good quality and of most importance to the readers has been included. This information will be expanded and improved over the years. Subsequent "state of the environment" monitoring reports will therefore provide a more complete picture of the state of, and pressures on, the regional environment, along with more extensive links to other resource management agencies.

1 INTRODUCTION

Tasman District Council (TDC) monitors surface water quality to fulfil its responsibilities under the Resource Management Act (RMA 1991) and the Tasman Resource Management Plan (TRMP). The RMA (1991) imparts to regional councils a function of maintaining and enhancing the quality of natural water (Section 30) and directs councils to gather information so that they can effectively carry out these functions (Section 35). The TRMP identifies the degradation of water quality as an issue and seeks to maintain and improve the quality of fresh and marine waters in the District. The TDC's State of the Environment (SoE) monitoring programme aims to gather appropriate data to fulfil these responsibilities.

Tasman District covers an area of northern South Island from Golden Bay (including most of Kahurangi National Park in the west), Tasman Bay (including the Motueka River Catchment) to Richmond (near Nelson in the east), to upper Buller (including the lower half of the Maruia River in the south). There are 9,253 kilometres of waterways in the District, over 90% of which are situated in a cool extremely wet or cool wet climate (from Snelder, 2004). Most streams are fed from hills (51%) or low elevations (24%), with mountain-fed waterways making up about 25% of waterways. The influence of geology on waterways is mostly sedimentary (soft sedimentary 38% and hard sedimentary 31%), with 6% alluvium and 21% plutonics. Sixty percent of waterways are dominated by indigenous forest, pasture 17% and exotic forest 9%. Over 77% of waterways are on smaller (first to third order) waterways, with 72% having a high gradient.

1.1 The Pressure-State-Response Model

Implementation of TDC's SoE monitoring programme is based on the pressure-state-response framework (Figure 1). This framework was used in *State of New Zealand's Environment* (Ministry for the Environment, 1997) report, and is based on a concept of causality. Human activities exert **pressures** on the environment, such as pollutant discharges or over-use of a resource, changing both the quality and quantity of natural resources. These changes alter the **state** or condition of the environment, which can then be assessed by measuring various aspects of the environment. The human **responses** to these changes include any actual organised behaviour that aims to reduce, prevent or mitigate undesirable changes. Pressures from natural sources are not considered in this framework as they are generally not controllable.

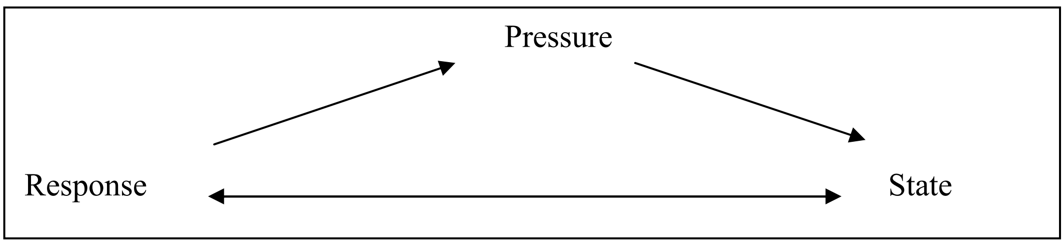


Figure 1 The Pressure-State-Response Model of Environmental Change

Under this model SoE monitoring seeks to identify changes in the state of the environment, particularly degraded or declining states, so that the pressures causing the identified changes can be found, allowing the Council to formulate an appropriate response. This model is used in the discussion of results (see Section 6 of this report).

1.2 Programme Design

The Surface Water Quality Monitoring Programme (SWQMP) forms part of the Council's broader SoE monitoring programme. Under this programme data on water quality, periphyton (algae on the stream bottom) and stream invertebrates have been gathered from selected rivers and streams since 1999. Additional information has also been collected during the Council's bathing water surveys and as part of scientific studies carried out by other agencies in the District.

The specific aims of the SWQMP are:

1 To determine the quality of surface waters in the District in reference to accepted standards (for public health, recreational and ecological reasons).

2 To identify short and long term trends in water quality (bearing in mind that accurate trend analysis on quarterly data is only achievable after 15-20 years of data collection).

3 To identify cumulative environmental effects from multiple discharges into surface waters.

4 To understand the nature of surface water quality problems/issues in order to provide information that enables defensible management responses to be enacted. Such responses include seeking reviews to Council resource management plans, regulations, and resource consent conditions.

5 To identify new issues and monitoring requirements.

6 To identify factors that cause change in surface water quality (i.e. impact monitoring).

The SWQMP was designed to achieve the six aims outlined above. However, the programme must work within a number of constraints. Given the resources available, quarterly sampling is undertaken. Sampling only occurs at base flow so very little is known about water quality after rain or flood flow conditions. For the Contact Recreation Water Quality Monitoring Programme (mostly bathing beaches or swimming holes), sites are sampled biweekly or weekly from November-March irrespective of rainfall.

While information from the SWQMP will give clues as to the cause of poor water quality, it is often only after intensive sampling within a catchment that clear conclusions of cause and effect relating to specific land-use activities can be drawn. Such follow-up investigations are undertaken on a prioritised basis.

The programme targets areas where the most significant human pressures, such as point source discharges, exist or are suspected, while maintaining a few sites in pristine areas for reference sites (eight sites out of a total of 50). Sites in the programme were chosen to try to achieve a balance within and between the following criteria:

(a) geographical spread throughout the District;

(b) range of waterway sizes represented (from large main-stem rivers to small creeks);

(c) range of different environmental pressures represented at different sites;

(d) in areas with high human use (such as for recreation or drinking) or significant ecological values.

In order to address its aims while working within the constraints mentioned above, design of the SWQMP involved careful choice of indicators (measures) of water quality, sites, and methods. In addition to the intrinsic ecological values of waterways the issue of water quality is also related to community values. Therefore, the choice of environmental indicators may differ between monitoring sites with different values. For example, one stretch of river may be highly valued as a fishery resource, but may be seldom used for swimming, while another may be popular for swimming. In this example water clarity, ammonia and macroinvertebrates would be the most important indicators for a river valued for its fishery, but faecal bacteria (*E. coli* and faecal coliforms), which are indicators of potential human disease, would be the most crucial indicators at monitoring sites valued for contact recreation. Indicators were, therefore, chosen partly to reflect community values, as well as to be consistent (as far as practical) with indicators recommended by Ministry for the Environment (1998).

In this report we summarise information from TDC's SWQMP, along with data from other long-term monitoring programmes in the area, and identify the state of water quality and ecosystem health of rivers and streams throughout the Tasman District. The length of the data record at most of the sampling sites in the District is insufficient for determining trends in the parameters monitored, however, three sites are part of the National River Water Quality Network and have been sampled monthly since 1989, allowing trends to be identified.

Further information on the design of the monitoring programme and methods used can be found in the Tasman District Council, Surface Water Quality Monitoring Programme document (January 2005).

2 SAMPLING SITES

2.1 Water Quality

Water quality information reviewed here has been collected from 89 sites throughout the Tasman District. However, the analyses presented in this report focus on 70 of these sites, which have been sampled at least three times (Figure 2). Most sites in the SWQMP (Appendix 1) have been sampled on a quarterly basis since late 1999 and thus have been sampled 15-20 times. The main exceptions to this are sites included in the Motueka Integrated Catchment Management (ICM) programme (for further details see http://icm.landcareresearch.co.nz), which have generally been sampled quarterly as part of the SWQMP, but were sampled monthly from October 2000 – October 2001 at all flows. Sites sampled as part of bathing water surveys have been monitored weekly/fortnightly each year over the swimming season (November-March). Three sites in the Tasman District (Motueka Rv at Gorge, Motueka Rv at Woodstock, Buller Rv at Longford) are part of NIWA's National River Water Quality Network (NRWQN) and have been sampled monthly since 1989 using a standardised protocol (Smith & Maasdam, 1994).

The range of parameters that have been measured at each site varies depending on the aims of the particular sampling programme. For example, bathing water surveys involved only spot measurements of faecal indicator bacteria, while sampling at the SWQMP sites was undertaken using the protocols detailed in Tasman District Council's Surface Water Quality Monitoring Programme document (latest revision: January 2005) (see Appendix 3 for an explanation of the variables measured and their applications in terms of assessing the state of the environment). Spot field measurements of temperature, dissolved oxygen, pH, specific conductivity and turbidity were measured using standard meters (YSI 85, YSI 650, Orion 210A, Hach 2100P), while visual water clarity was measured using a black disc (Davies-Colley, 1988). River flow was determined using either; velocity and depth measurements across the river cross-section, or from permanent stage-height recorders at the sites. Samples were collected for laboratory analysis of nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), total nitrogen (TN), dissolved reactive phosphorus (DRP), total phosphorus (TP), total suspended solids (TSS), fixed (inorganic) suspended solids (FSS), volatile (organic) suspended solids (VSS) and faecal indicator bacteria (*E. coli*). Samples were transported to the Cawthron Institute's IANZ accredited laboratory in chilly bins for analysis.

Chemical and microbiological analyses were conducted using standard analytical techniques (APHA, 1998). Recent laboratory reporting limits for the chemical analyses were: NO_3-N 0.002 mg/L; NH_4-N 0.005 mg/L; TN 0.1 mg/L; DRP 0.005 mg/L; TP 0.005 mg/L, TSS 0.3 mg/L, FSS 0.3 mg/L, VSS 0.3 mg/L and *E. coli* 5 cfu/100mL. In cases where water quality data were below the reporting limit for a particular chemical analysis we substituted a value of half the reporting limit for the calculation of statistics.

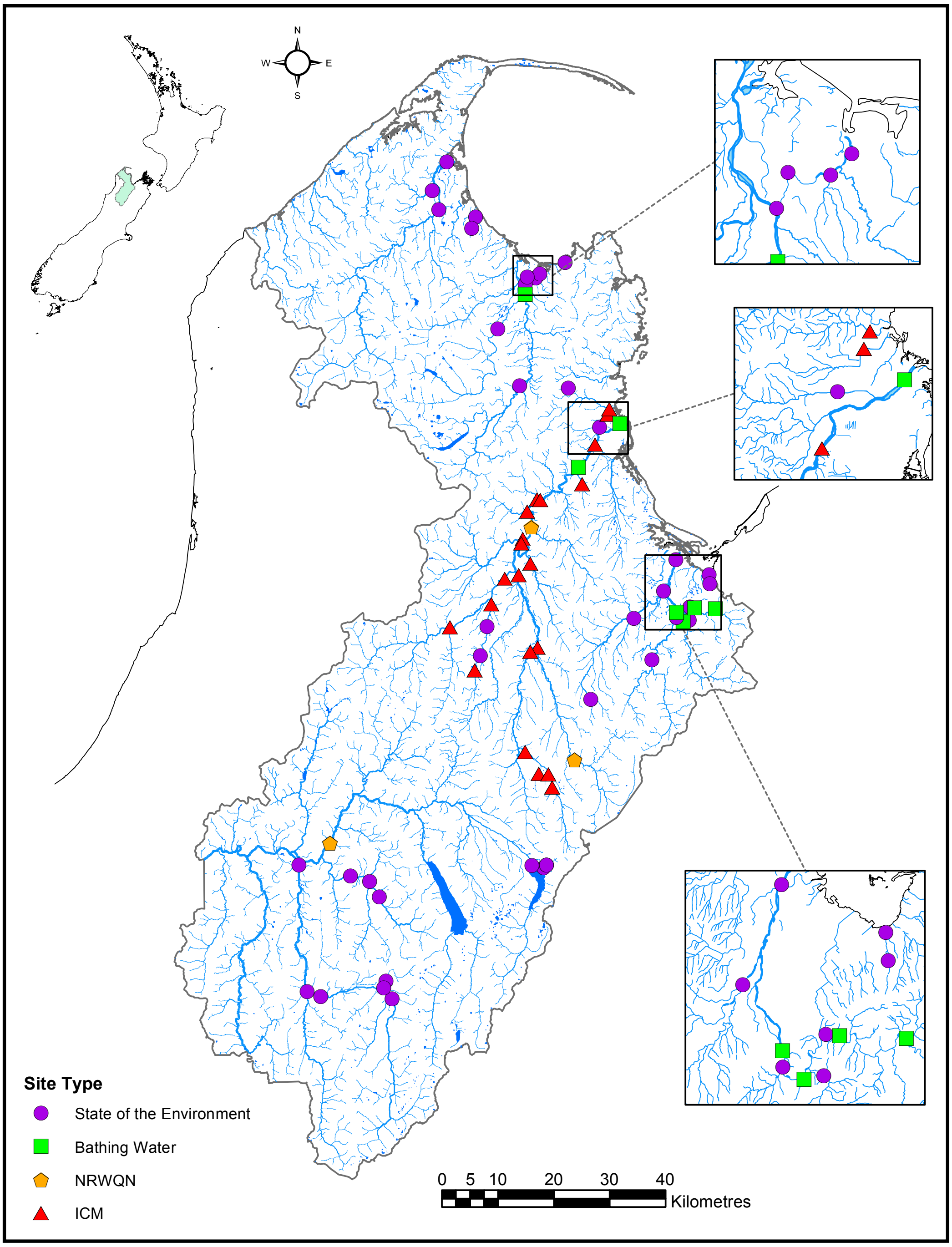


Figure 2 Water quality monitoring sites throughout the Tasman District
NRWQN = National River Water Quality Network sites
ICM = Integrated Catchment Management programme sites

The quarterly sampling has generally been carried out after at least a short period of stable weather throughout the District and therefore represents "base-flow" conditions. In contrast, the three NRWQN sites are sampled on set days each month and therefore include measurements over a wide range of flow conditions.

2.2 Macroinvertebrates

Aquatic macroinvertebrates are small animals (0.5-60 mm in length) that spend most of their lives in streams, rivers, lakes and wetlands. They include insects (e.g., mayflies, stoneflies, caddis flies, true flies), crustacea (e.g., amphipods), worms and snails. These 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 particular macroinvertebrate species can indicate the ecological health of a site.

The macroinvertebrate data reviewed here has been collected at 83 sites throughout the Tasman District (Figure 3). These sites include TDC's SWQMP sites that have been sampled annually in spring since 2000 (four samples) and three NIWA National River Water Quality Network sites that have been sampled annually since 1989 (15 samples). The review also includes sites that were chosen for a 2002 study of macroinvertebrate populations around the Motueka River catchment as part of the ICM research programme. Macroinvertebrate samples were collected after a period of at least two weeks following a rainfall event that elevated flows >2.5 times the base flow.

Macroinvertebrate data from TDC's SWQMP sites are calculated from single hand net samples collected from each site (Protocol C1, Stark et al. 2001), whereas the NIWA data is calculated from seven pooled surber samples collected from each site. Three surber samples and a hand net were collected from each site in the ICM macroinvertebrate study. For all macroinvertebrate studies, samples were preserved in the field and then transferred back to the laboratory for taxonomic analysis. Samples were sorted to the lowest possible taxonomic level possible using standard identification keys. Macroinvertebrates from surber samples were counted, whereas relative abundances of each taxa were calculated from hand net samples.

Several different indices of river ecosystem health were calculated from the data and include:-

Species richness (or more strictly, taxa richness). This is simply the number of different types 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. In general terms, high species richness may be considered good, though often mildly impacted or polluted rivers with slight nutrient enrichment can have higher species richness than naturally "healthy" streams and rivers.

EPT** taxa.* This is the total number of types of mayflies (E**phemeroptera*), stoneflies (***P**lecoptera*), and caddis flies (***T**richoptera*) found in a sample. These kinds of freshwater insects generally are intolerant of pollution. Two types of caddis flies (*Oxyethira, Paroxyethira*) are often found in enriched streams and thus were not included in the counts of sensitive EPT species. The percentage of EPT species compared to the total number of species found at a site provide an index of health, with high percentages considered to indicate good health.

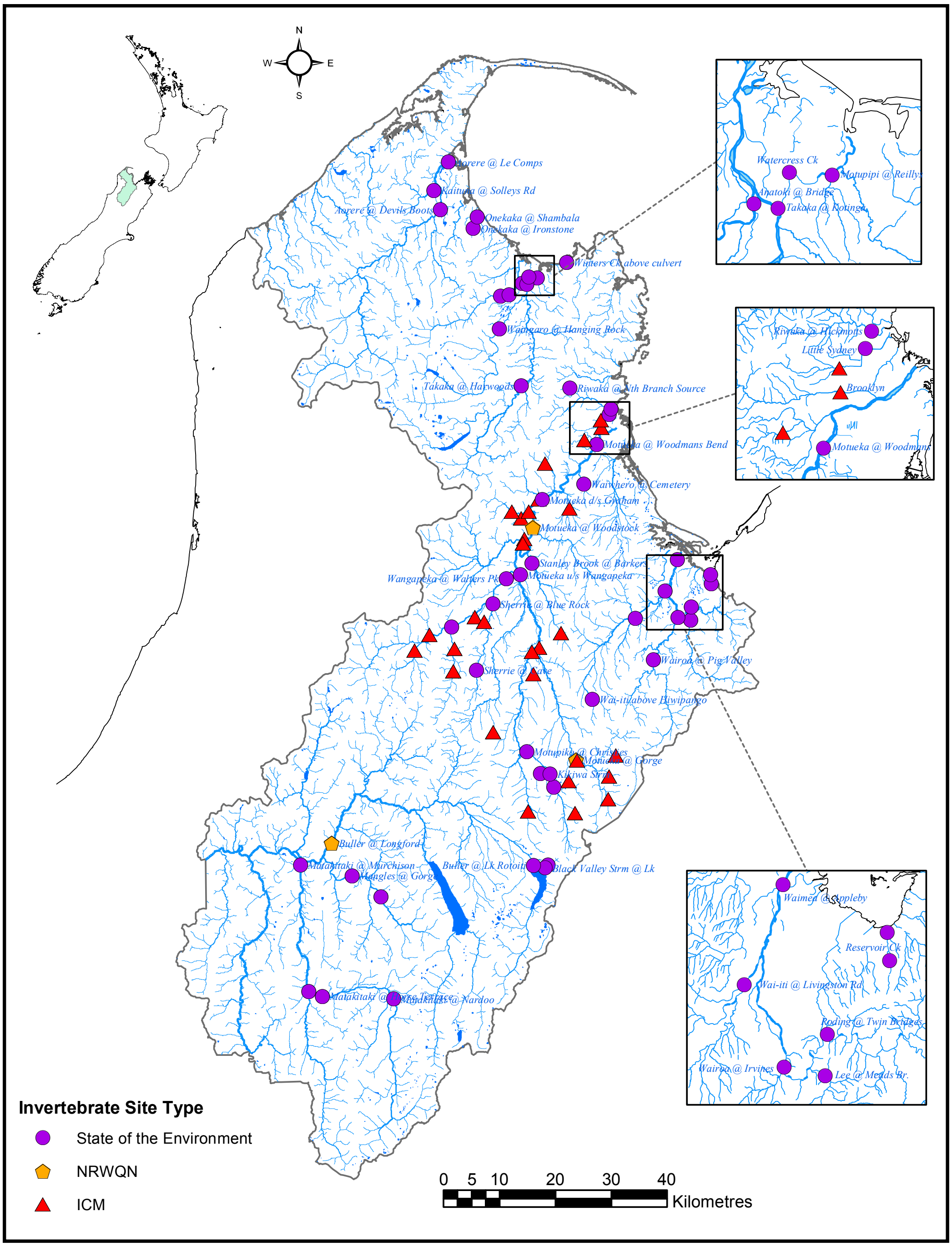


Figure 3 **Macroinvertebrate monitoring sites throughout the Tasman District**
NRWQN = National River Water Quality Network sites
ICM = Integrated Catchment Management programme sites
(Periphyton was also monitored at State of the Environment sites)

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. Macroinvertebrates that are characteristic of unpolluted conditions score more highly than those found predominantly in polluted conditions. In theory, MCI values can range between 200 and 0, but in practice it is rare to find MCI values greater than 150. Only extremely polluted or sandy/muddy sites score under 50. This index is designed specifically for stony riffle substrates in flowing water, therefore interpretation of scores requires some knowledge of the types of habitat where the samples were collected.

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 both the abundance and types of macroinvertebrates found at a site and thus respond to more subtle changes in macroinvertebrate community composition than the MCI.

2.3 Periphyton

The amount and types of periphyton (or algae) growing on the river bed is also indicative of the river ecosystem health. Excessive growth of filamentous green algae is typical in unshaded sites that have abundant nutrients. These growths are often unsightly and can reduce the quality of habitat for other river life. In more healthy systems periphyton growths are dominated by thin films or mats of brown diatoms, which form an important food source for some types of macroinvertebrates.

Periphyton data was only available from TDC's SWQMP sites (Figure 3) and has been measured quarterly since October 2001. Periphyton assessments were based on Rapid Assessment Method 2 (RAM-2) from Biggs & Kilroy (2000). This involves estimating the percentage cover of all algae present, classified according to their appearance (e.g., growth-form and colour), at a number of regularly spaced points across five transects. The percentage cover values are weighted according to the pollution tolerance of each algal classification, and are then combined to give an overall score for the site ranging between 1 and 10 (1 indicating a site with highly degraded water quality and a score of 10 indicating a healthy site with good water quality). The TDC's methodology varies from that outlined by Biggs & Kilroy (2000) in that clean substrate is given a score of 10 (along with pollution intolerant classes of algae), rather than scoring 0.

3 WATER QUALITY

3.1 Patterns Across Sites and Exceedance of Guidelines

Box plots showing median values and the distribution of data points at each site for each water quality parameter are shown in Appendix 3. These box plots give a detailed summary of the results from each site, but are somewhat difficult to read given the large number of sites. An alternative way of viewing the state of water quality throughout the District is to compare results with guideline water quality values (Table 1). The proportion of the samples collected from each site that either meet or exceed these guidelines is shown in Figures 4-13.

Table 1 Guideline water quality values for protection of river ecosystem and human health

Parameter	Guideline Value	Reference
Dissolved oxygen	>80% Saturation or >6.5 mg/L	ANZECC (1992)
pH	5 - 9	CCREM (1987)
Clarity	>1.6 m	ANZECC & ARMCANZ(2000)
Turbidity	<5.6	ANZECC & ARMCANZ(2000)
Total nitrogen	<0.614 mg/L	ANZECC & ARMCANZ(2000)
Dissolved inorganic nitrogen	<0.444 mg/L	ANZECC & ARMCANZ(2000)
Dissolved reactive phosphorus	<0.01 mg/L	ANZECC & ARMCANZ(2000)
Total phosphorus	<0.033 mg/L	ANZECC & ARMCANZ(2000)
E. coli	<260 cfu/100 mL Acceptable 260-550 cfu/100 mL Alert >550 cfu/100 mL Action	MfE & MoH (2003)

3.1.1 Dissolved Oxygen

Dissolved oxygen concentrations were close to saturation at most sites sampled (Figures 4 and 5). The only site with consistently low dissolved oxygen was Watercress Ck at u/s factory. This was not surprising considering the spring-fed nature and the abundant growth of aquatic plants in this stream. Dissolved oxygen concentrations were occasionally also low in Waiwhero Ck, but these low concentrations coincided with periods of extremely low (or zero) flow. Occasional low measurements at other sites may also have been the result of seasonal low flows.

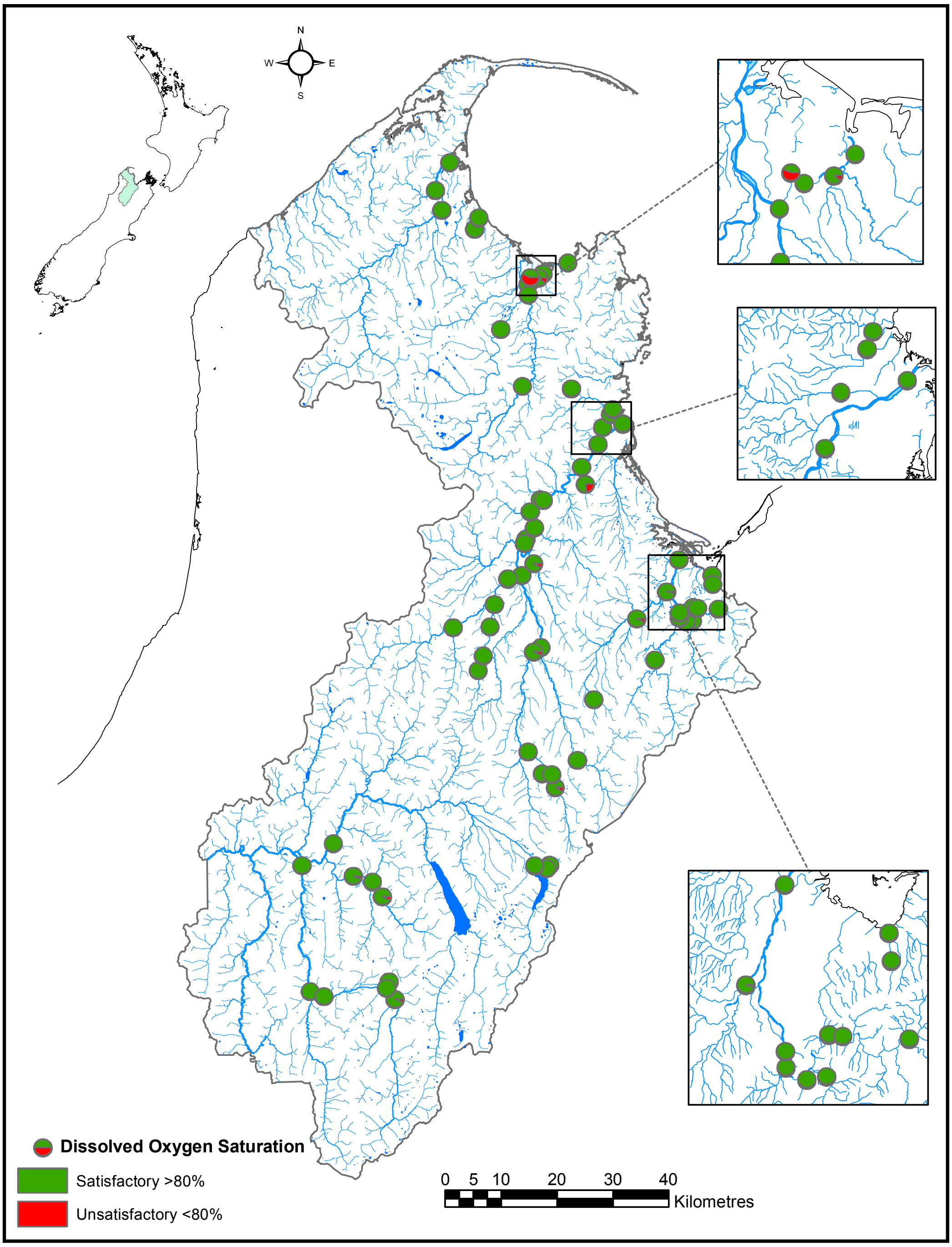


Figure 4 **Proportion of dissolved oxygen (% Saturation) measurements at each site that met or exceeded guidelines**

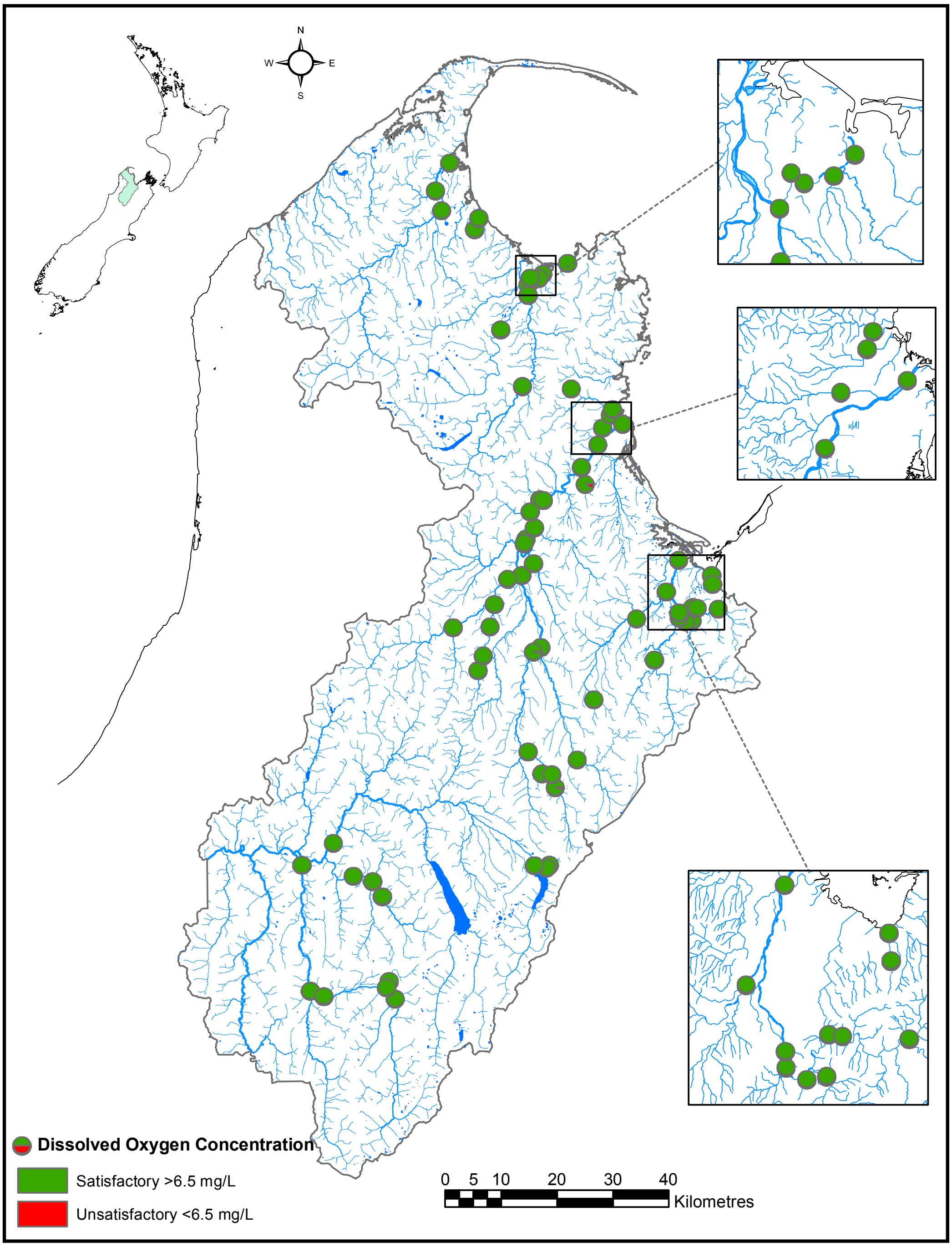


Figure 5 Proportion of dissolved oxygen (mg/L) measurements at each site that met or exceeded guidelines

3.1.2 pH

Measurements of pH at most sites were also generally within the guidelines (Figure 6). The few exceedances were found in the western tributaries of the Motueka River (Wangapeka, Graham River, Riwaka), which drain karst (marble) terrain. Water draining this terrain becomes enriched in carbonates, resulting in the high pH recordings.

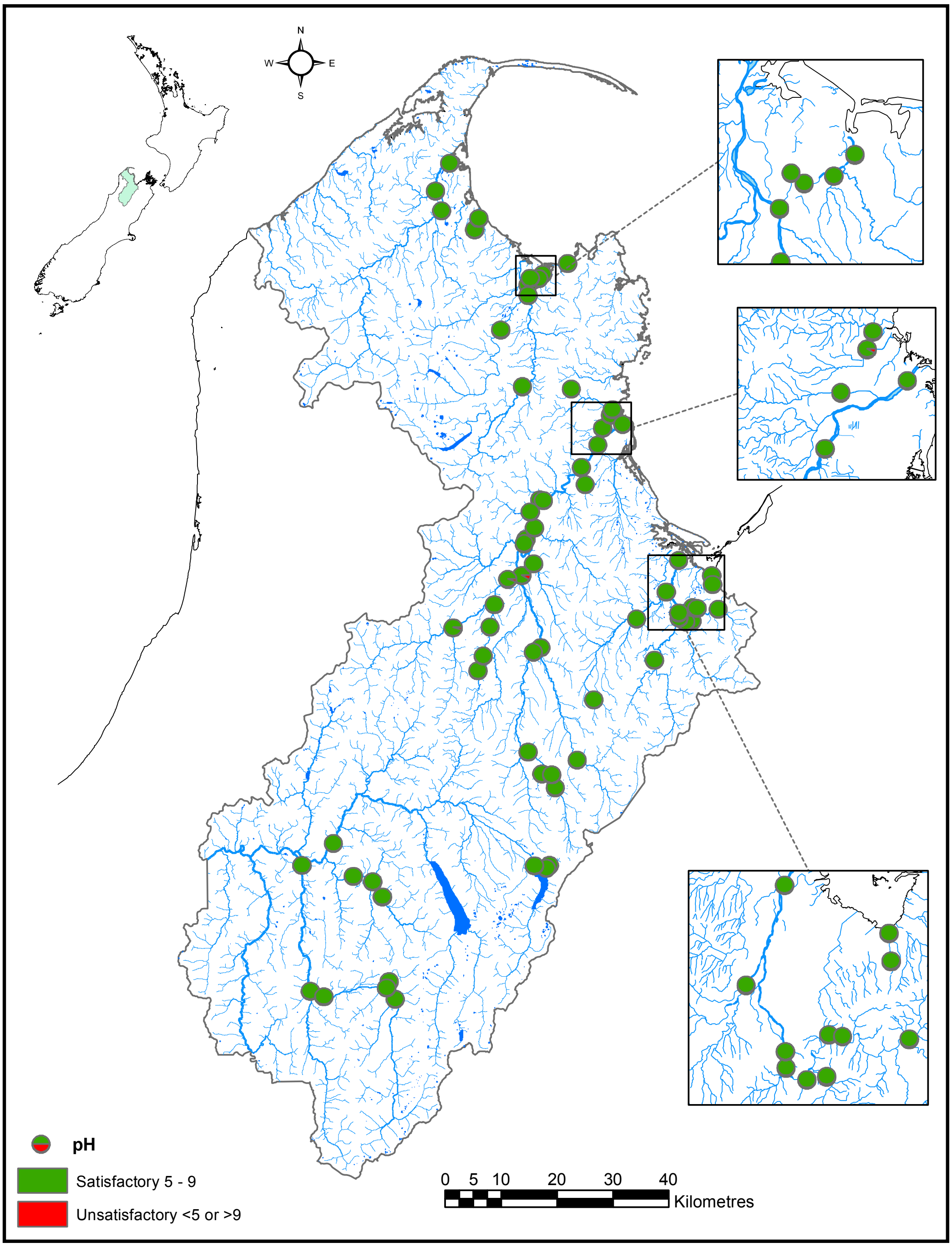


Figure 6 Proportion of pH measurements at each site that met or exceeded guidelines

3.1.3 *Nitrogen*

Concentrations of total nitrogen and dissolved inorganic nitrogen (nitrate nitrogen plus ammonium nitrogen) exceeded guideline values regularly at some sites (Figures 7 and 8). Particularly high concentrations were observed at Reservoir Ck (particularly downstream of Salisbury Rd), Motupipi Rv at Reillys, Winter Ck, Stanley Brook at Barkers, Wai-iti Rv at Livingstone Rd, and Wai-iti Rv at Pigeon Valley Bridge. The Reservoir Ck and Winter Ck sites are heavily influenced by urban land use. The Motupipi River also had very high coverage of the bed with aquatic plants, which is also partly due to its spring-fed character with stable flow conditions. The catchment is predominantly in pastoral farming. No obvious improvement in total nitrogen could be determined from results for Motupipi Rv at Reillys following wastewater treatment upgrades at the dairy factory in 2003-03.

The single sample taken at Takaka Rv at Paynes Ford also contained high concentrations of total nitrogen and dissolved inorganic nitrogen (Appendix 3.5 – 3.7). Other sites with moderate to high concentrations of the various forms of nitrogen include Kikiwa Stm, Little Sydney Ck, Motueka Rv at McLeans, Waimea Rv at Appleby, Waiwhero Ck, and Watercress Ck u/s of the factory (Appendix 3.5 – 3.7).

MacGibbon (2000) and Roberts (1993) showed that nitrate-nitrogen concentrations were very low in the headwaters of the Takaka River and gradually increased downstream. MacGibbon showed they peaked at 0.46 gm^{-3} at Paynes Ford. However, the headwaters site recorded higher ammonia-nitrogen, phosphorus and conductivity levels than most other sites; the reason for this is not known. The Paynes Ford results for periphyton and macroinvertebrates indicated poor condition. These results could have been due to poorly performing toilets. These facilities were upgraded after this issue was raised. A marked reduction in water clarity was measured between the Takaka River headwaters site and the Harwoods site approximately 15 kilometres downstream of the Cobb Power station discharge.

Nutrient concentrations in the Waikoropupu River are consistently relatively high over 10 years from 1990 to 1999 (nitrate range: 0.1-0.9 gm^{-3}) (Tasman District Council springs monitoring programme, unpublished data).

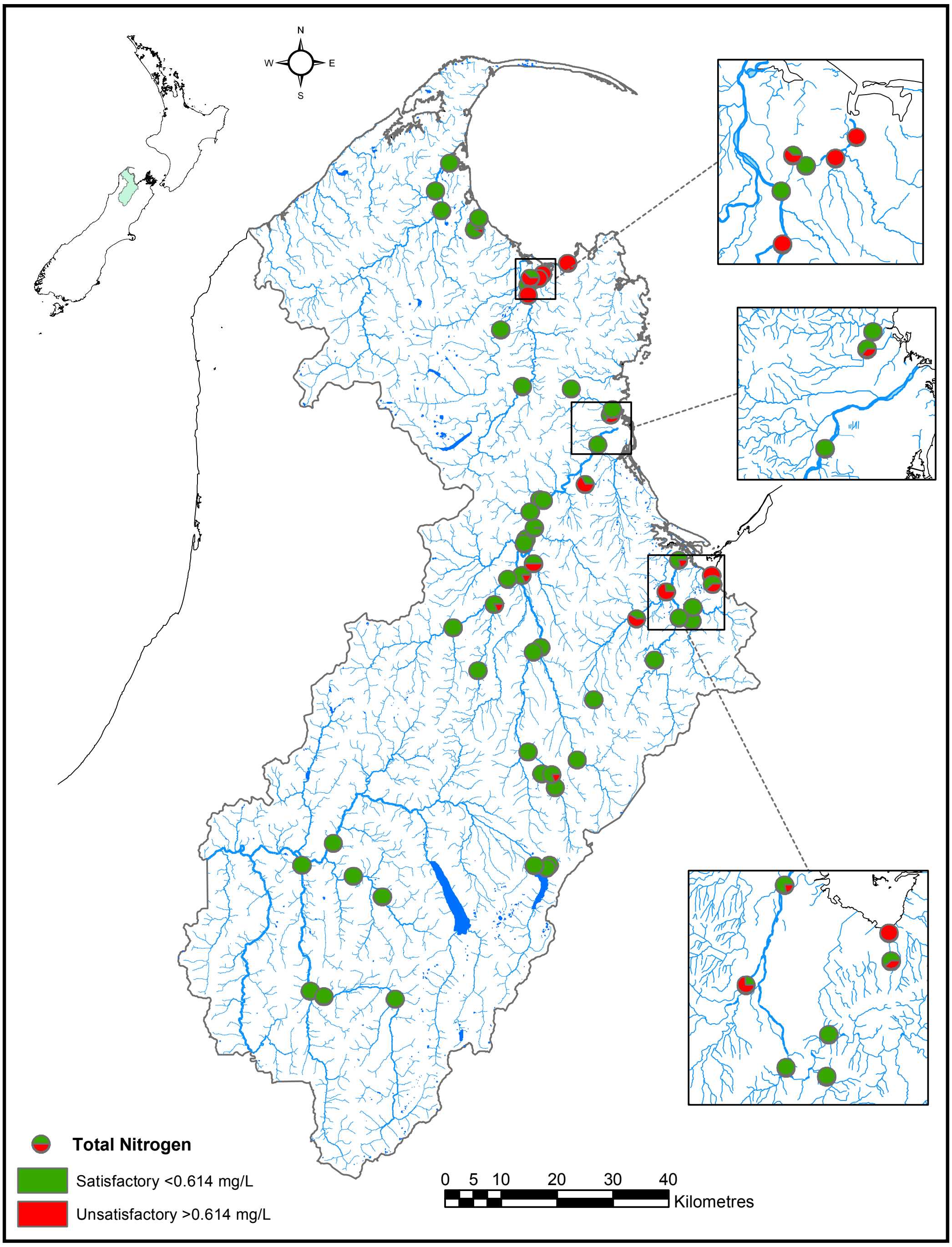


Figure 7 Proportion of total nitrogen measurements at each site that met or exceeded guidelines

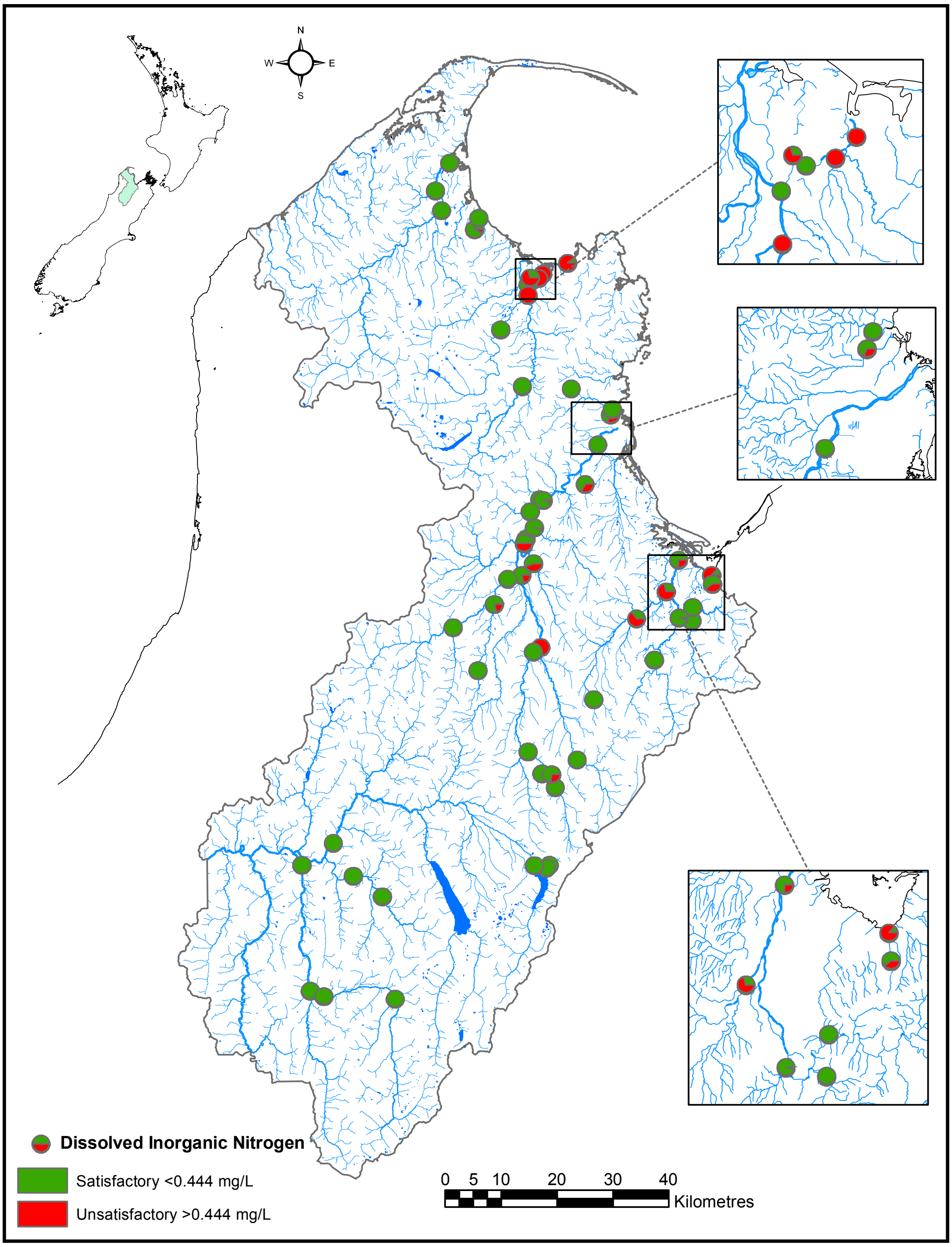


Figure 8 Proportion of dissolved inorganic nitrogen measurements at each site that met or exceeded guidelines

3.1.4 Phosphorus

Concentrations of total phosphorus (TP) and dissolved reactive phosphorus (DRP) regularly exceeded guidelines for control of algal growth at a relatively large proportion of sites throughout the District (Figures 9 and 10). Regular exceedance of TP and DRP guidelines occurred at both Reservoir Ck sites, Kikiwa Stm, Little Sydney Ck, Motupipi Rv at Reillys, Waiwhero Ck, Watercress Ck u/s of the factory, and Winter Ck (Appendix 3.8). Concentrations of DRP also regularly exceeded guideline values at Kikiwa Ck, Hunters Ck, Motupiko Rv at Christies, Motupiko Rv at Quinneys, Baton Rv, Motueka Rv at McLeans, Pearse Rv, Riwaka Rv at Hickmotts, Kaituna Rv at Sollys, Tiramea Rv at Track, and Wai-iti Rv above Hiwipango.

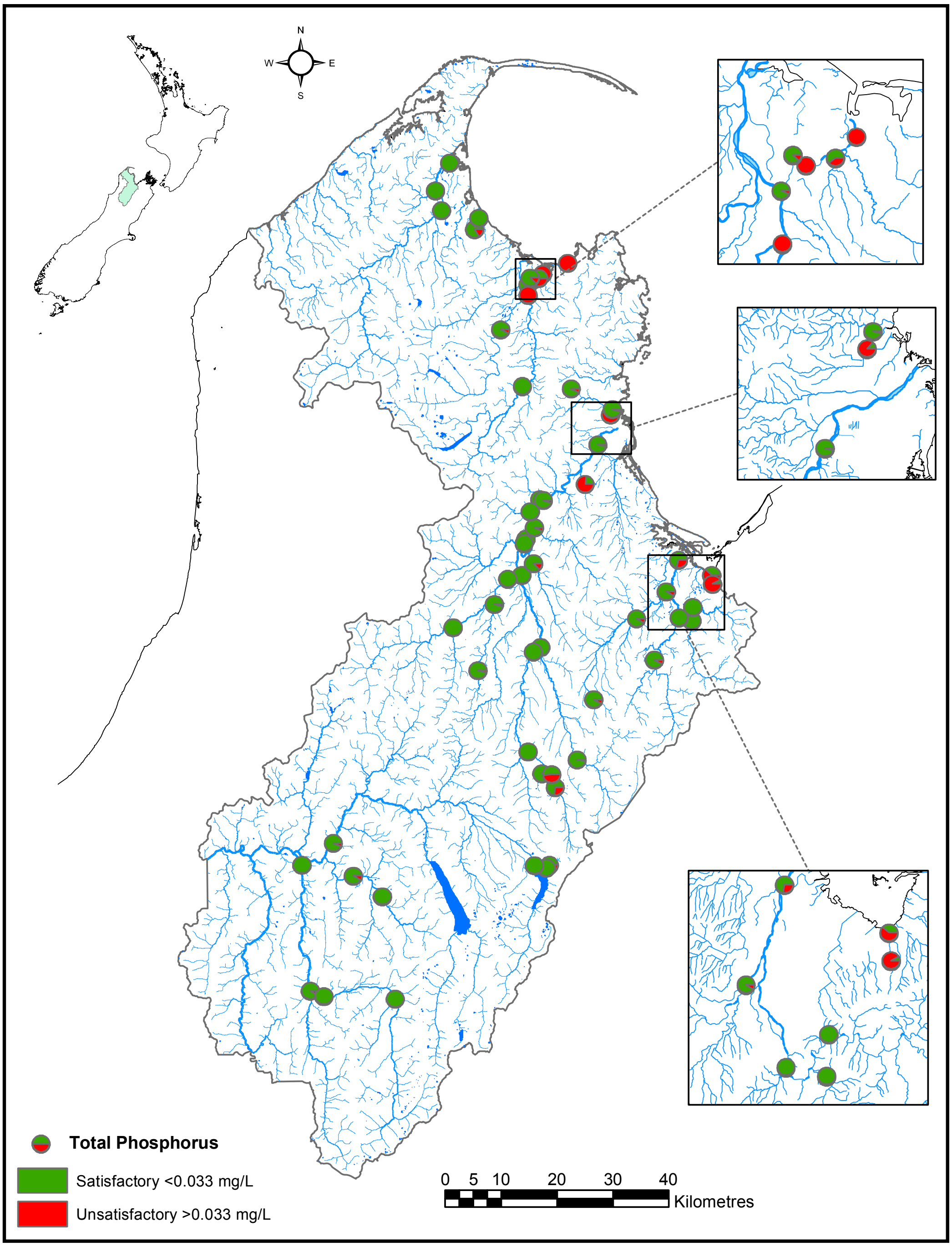


Figure 9 Proportion of total phosphorus measurements at each site that met or exceeded guidelines

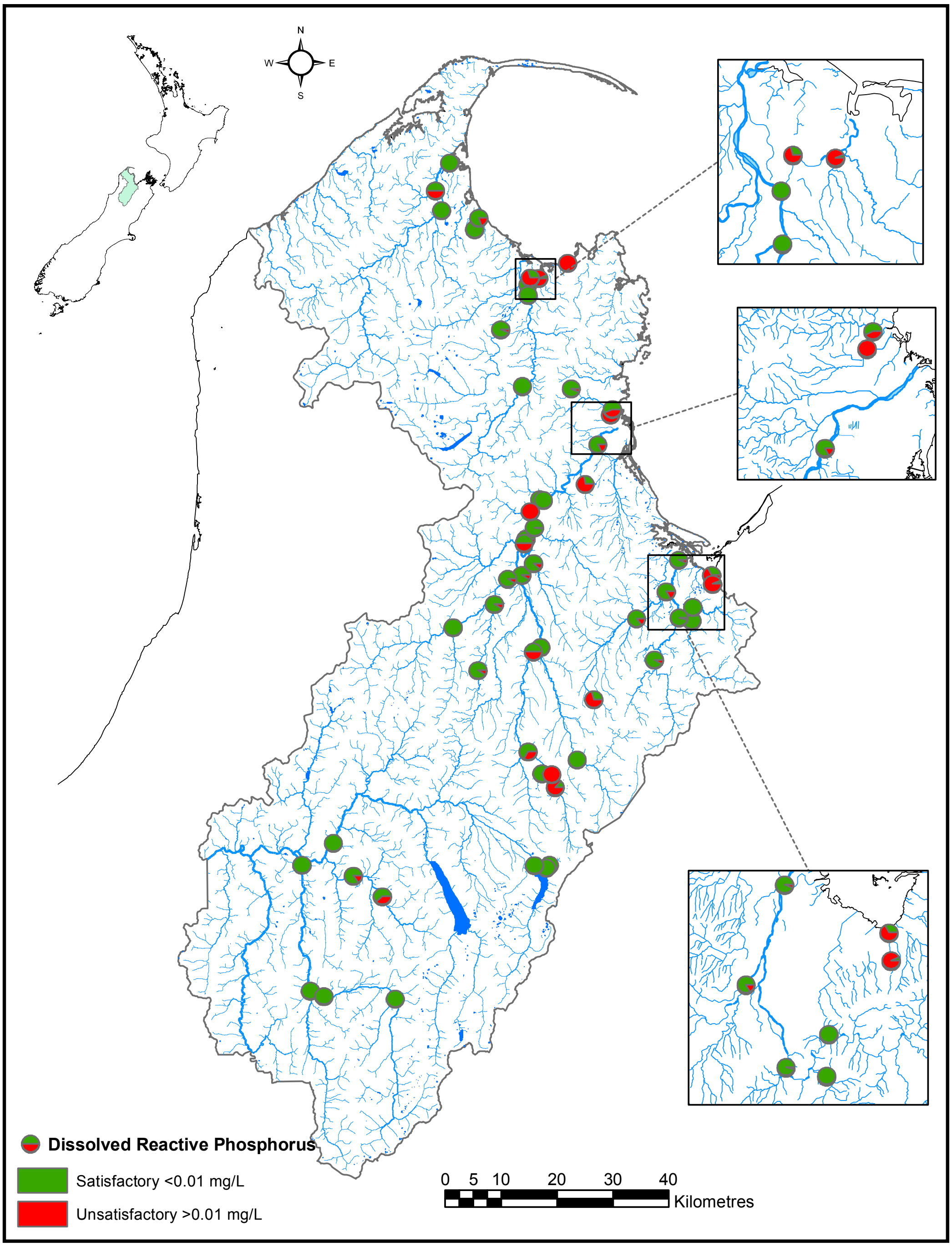


Figure 10 Proportion of dissolved reactive phosphorus measurements at each site that met or exceeded guidelines

3.1.5 *Clarity and Turbidity*

Water clarity was high (and turbidity low) at most sites throughout the District and the clarity guidelines were only rarely exceeded for the majority of sites (Figures 11 and 12). Exceptions to this were Winter Ck and the two sites on Reservoir Ck which consistently have poor water clarity. Kikiwa Stm, Little Sydney Ck and Waiwhero Ck also have relatively low water clarity (Appendix 3.11). The long sampling record at the NRWQN sites (Motueka Rv at Gorge, Motueka Rv at Woodstock, Buller Rv at Longford) means that a considerable number of samples have been collected under high flow conditions and water clarity at these times is often low (Figure 11, Appendix 3.11). Clarity at Motupipi River is much lower than expected for a spring-fed creek. For interest the maximum recorded water clarity of the Waikoropupu Springs was 62m (NIWA, 1993).

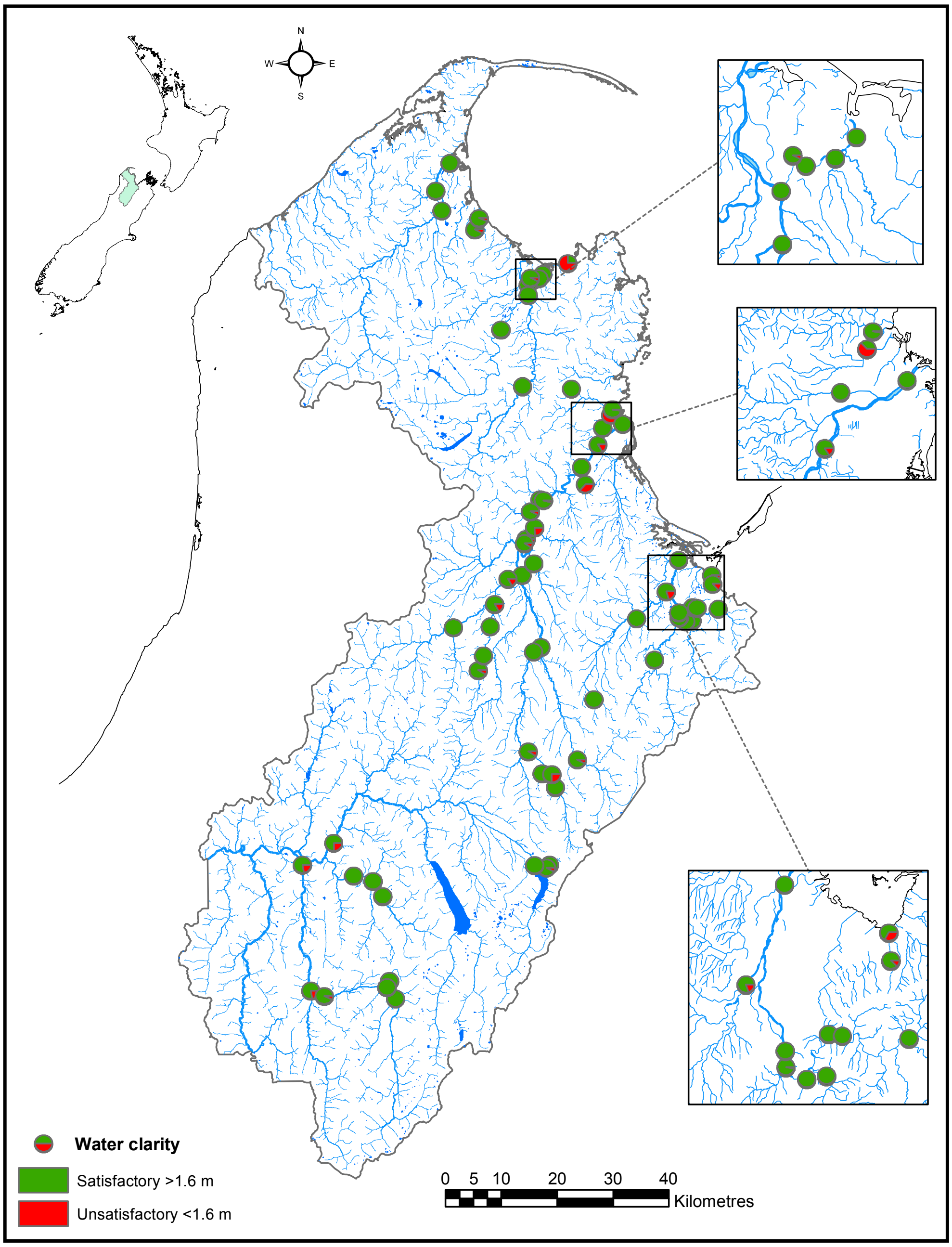


Figure 11 Proportion of water clarity measurements at each site that met or exceeded guidelines

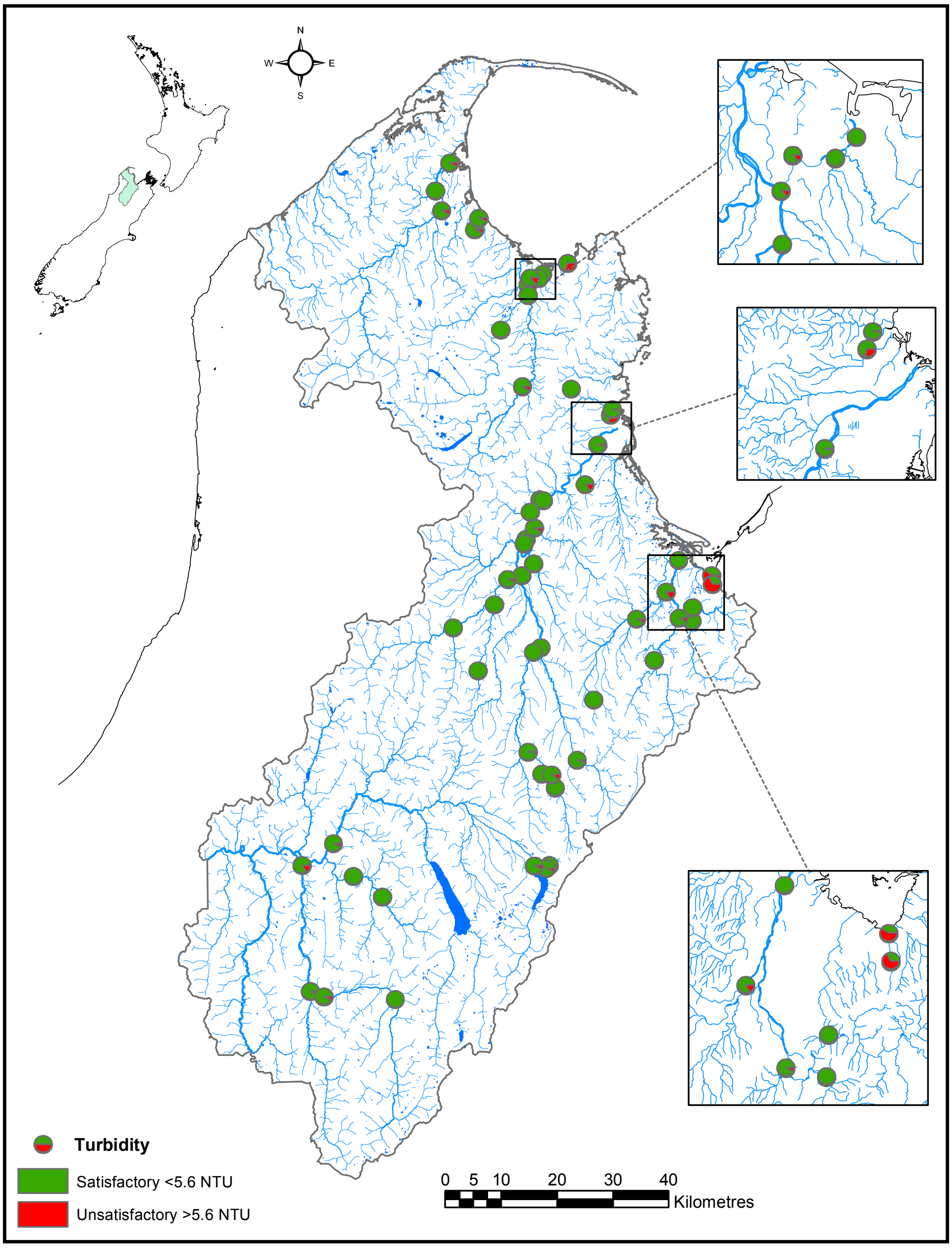


Figure 12 Proportion of turbidity measurements at each site that met or exceeded guidelines

3.1.6 Faecal Indicator Bacteria

Concentrations of *E. coli* regularly exceeded the "action" limit guideline for contact recreation at Kikiwa Stm, Little Sydney Ck, Mole Ck at Bridge (near Murchison), Motupipi Rv at Reillys, both Reservoir Ck sites, Sherry Rv at Blue Rock, Sherry Rv at Matariki Bridge, Onekaka Rv at Shambala, Watercress Ck u/s factory, and Winter Ck (Figure 13; Appendix 3.10). The catchments of these waterways are dominated by dairy or sheep/beef farming or urban (Reservoir Ck). Nottage (2000) showed *E. coli* loadings in the Aorere Rv tributary, Kaituna Rv at Sollys had loadings of over 130 Billion *E. coli* during one 3 hour rainfall event.

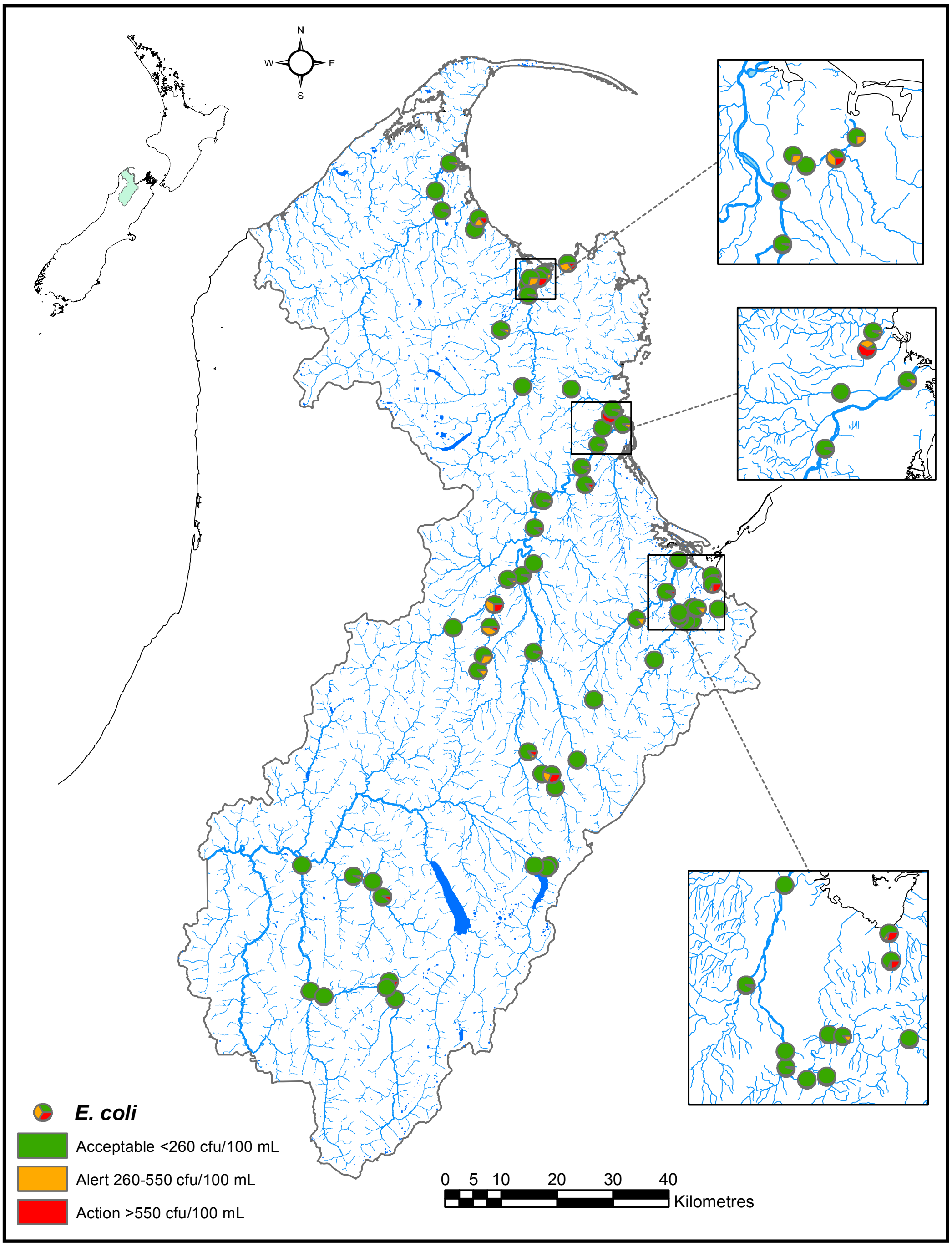


Figure 13a Proportion of faecal indicator bacteria measurements at each site that met or exceeded guidelines for contact recreation

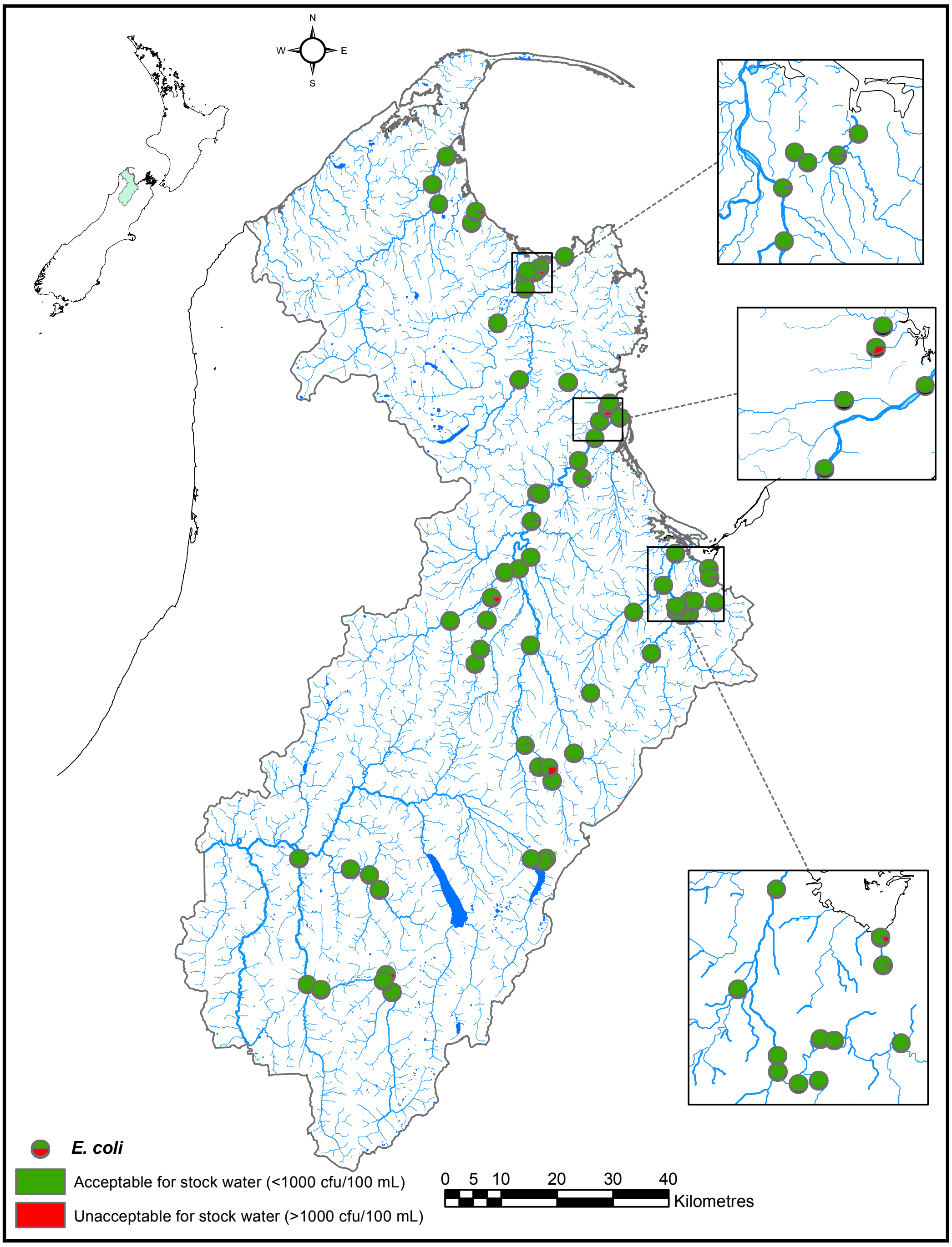


Figure 13b Proportion of faecal indicator bacteria measurements at each site that met or exceeded guidelines for stock drinking.

3.2 Site Groupings

To identify groups of sites with similar characteristics a hierarchical cluster analysis was conducted using the water quality data. This technique considers all the different water quality parameters together and calculates a "distance" between sites depending on their similarity in terms of water quality. All variables were log transformed to improve the normality of the data before analysis. The cluster analysis identified three distinct groupings of sites – red sites, yellow sites, and green sites (Figure 14).

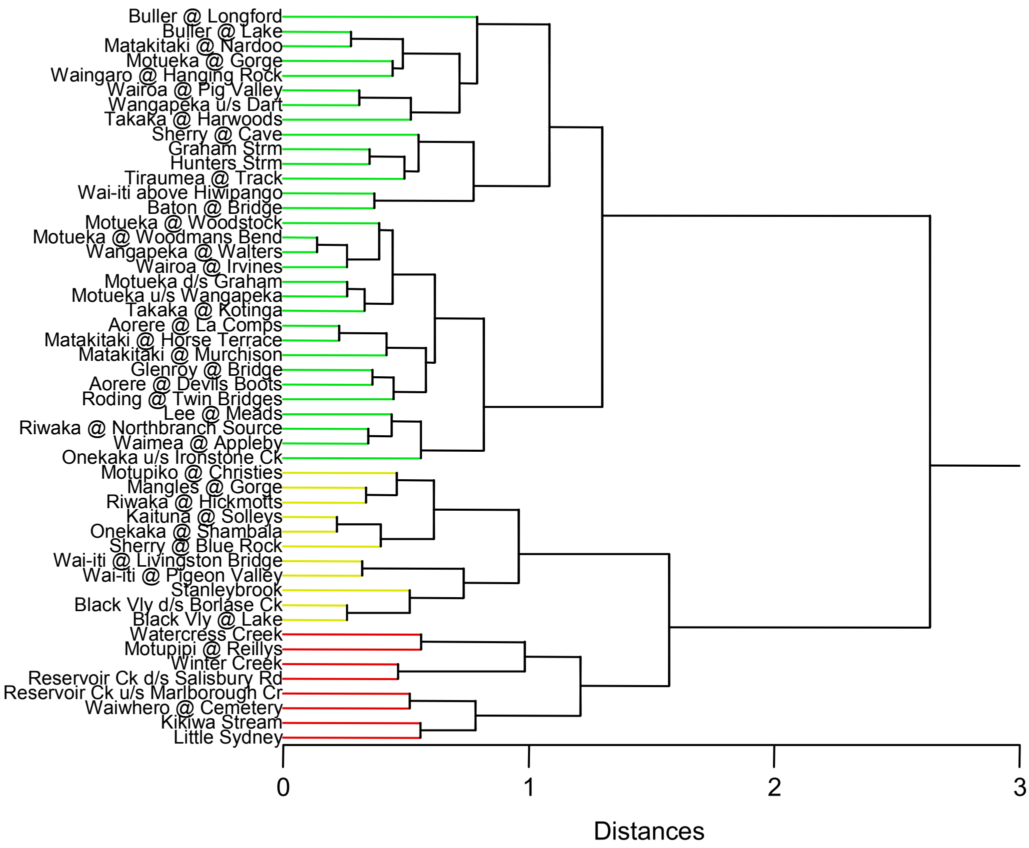


Figure 14 Clustering of the sites based on their water quality

A Principal Components Analysis (PCA) was used to help identify the characteristics that separated each group of sites. 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 53.1% of the total variance in the data and was highly correlated with turbidity, water clarity and the concentrations of nitrogen, phosphorus and faecal indicator bacteria. The second principal component (PC2) explained 17.6% of the variance in the data and was highly correlated with pH, conductivity and the concentration of dissolved oxygen. A plot of the principal component scores for each site is shown in Figure 15. Sites with similar characteristics are plotted closely together, while those with markedly different characteristics are plotted far apart.

The "red" sites tend to be at the right-hand side of the ordination (Figure 15) indicating that these sites tend to have poor water clarity and high concentrations of nutrients and faecal indicator bacteria compared with other sites throughout the District. These sites are typically the ones that exceeded the water quality guidelines discussed above (Section 3.1). Most of these sites are small streams draining lowland areas that have been intensively developed for agriculture or urban usage.

The yellow sites are roughly in the middle of the ordination (Figure 15) indicating that their water quality is intermediate between the poor quality (red) sites and the high quality (green) sites. The yellow sites include both small streams (e.g., Black Valley Stm) and moderate-sized rivers (Riwaka Rv at Hickmotts, Sherry Rv at Blue Rock, Mangles Rv at Gorge) and also tend to drain areas that are intensively developed for agriculture. It is notable that many of these yellow sites are downstream of "green" sites with higher water quality (e.g., Riwaka Rv at Hickmotts is downstream of Riwaka Rv at Northbranch Source, Sherry Rv at Blue Rock is downstream of Sherry Rv at Cave, Onekaka Rv at Shambala is downstream of Onekaka Rv upstream of Ironstone Ck, Mangles Rv at Gorge is downstream of Tiramea Rv at Track, and Wai-iti Rv at Livingston Rd and Wai-iti Rv at Pigeon Valley are downstream of Wai-iti Rv above Hiwipango.

The "green" sites have the highest water quality and include forested headwater sites and also downstream reaches of the large rivers in the District (e.g., Motueka, Takaka, Aorere, Buller, Waimea).

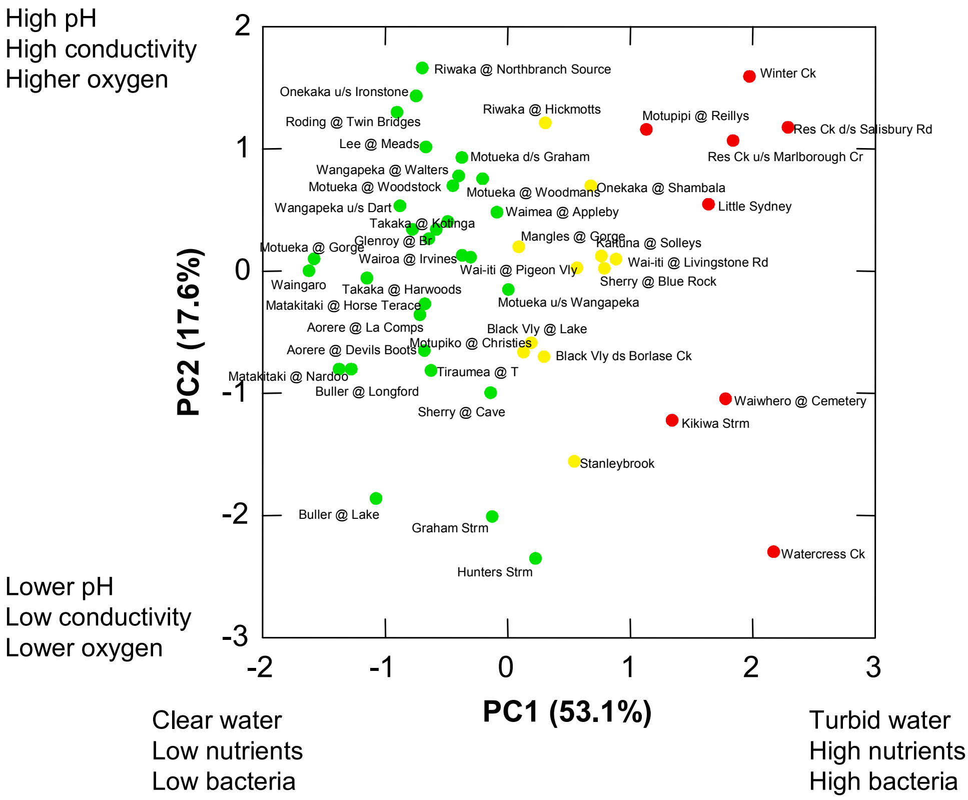


Figure 15 Ordination of sites based on their water quality
The colours refer to the site groupings from Figure 14 above.

3.3 Water Quality in Relation to the River Environment Classification Groupings

3.3.1 The REC System

The Ministry for the Environment, in conjunction with NIWA, has recently developed the New Zealand River Environment Classification (REC) system (Snelder et al., 2004). The REC groups rivers, or parts of rivers, at six hierarchical levels according to their climate, source of flow, geology, land cover, network position and valley landform. This system allows sections of rivers that are similar with respect to these factors to be grouped together for management purposes. The first four factors relate to the characteristics of the catchment upstream, while the factors of network position and valley landform are more specifically related to the site of interest. Within each factor there are a series of categories that are used to describe reaches of rivers throughout the country (Table 2).

Table 2 Summary of factors and categories used in the REC classification (from Snelder, 2004)

Factor	Categories	Code	Criteria
Climate	Warm extremely wet	WX	*Mean annual temperature:*
	Warm wet	WW	Warm ≥12 °C
	Warm dry	WD	Cool ≤12 °C
	Cool extremely wet	CX	*Mean annual effective precipitation:*
	Cool wet	CW	Extremely wet ≥1500 mm
	Cool dry	CD	Wet 500-1500 mm
			Dry ≤ 500 mm
Source of flow	Glacial Mountain	GM	*% permanent ice:*
	Mountain	M	Glacial Mountain >1.5%
	Hill	H	*Rainfall volume in elevation categories:*
	Low elevation	L	Mountain >50% above 1000 m
	Lake	Lk	Hill 50% between 400 – 1000 m
	Spring	Sp	Low elevation 50% below 400 m
	Regulated	R	*Lake influence index*
	Wetland	W	*Others manually assigned*
Geology	Alluvium	Al	*Spatially dominant geology category, unless:*
	Hard sedimentary	HS	soft sedimentary >25%, then classified as
	Soft sedimentary	SS	sedimentary
	Volcanic basic	VB	
	Volcanic acidic	VA	
	Plutonic	Pl	
	Miscellaneous	M	
Land cover	Bare	B	*Spatially dominant land cover class, unless:*
	Native forest	IF	pasture >25%, then classified as pasture
	Pastoral	P	urban >15% then classified as urban
	Tussock	T	
	Scrub	S	
	Exotic forest	EF	
	Wetland	W	
	Urban	U	
Network position	Low order	L	*Stream order:*
	Middle order	M	Low = 1 and 2
	High order	H	Medium = 3 and 4
			High >5
Valley landform	High gradient	H	*Valley slope:*
	Medium gradient	M	High >0.04
	Low gradient	L	Medium 0.02 – 0.04
			Low <0.02

The source of flow categories of "spring", "regulated" and "wetland" have not been developed for Tasman District at this stage.

There are a large number of karst springs in the district particularly in Mt Arthur marble country. Waikoropupu Springs is one of the world's largest cold-water springs with a mean flow of 13.2 m^3/sec with a stable mean temperature of 11.7^{o}C. The spring arises from one of the most important karst aquifers in New Zealand in terms of volume of water storage, the Takaka Valley. The marble aquifer extents for 180m^2 and is well over 500m thick. The average flow in the Takaka River is 16.1 m^3/sec but it loses up to 10-11 m^3/sec in its middle reaches. The river regularly dries up in summer.

Waterways with flow regulated include the Cobb/Takaka and Onekaka River Hydro schemes. There are a number of small dams on ephemeral streams, particularly in the Moutere, that are used for irrigation and may increase flows during drier periods.

Geology plays an important role in shaping aquatic communities particularly in the upper Motueka catchment where there are high concentrations of the heavy metals iron, nickel and chromium in stream sediment due to weathering of ultramafic rock. This occurs to a lesser extent in other streams draining the Red Hills in the eastern part of the district. Rivers draining marble geology have substantial low flows compared to Moutere Gravels.

3.3.2 Interpreting Water Quality Data With Respect to REC Groupings

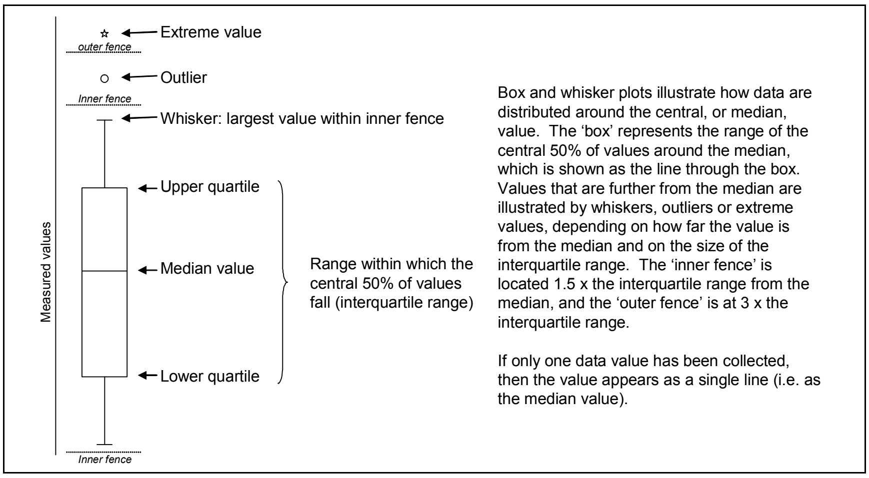
Using the REC system it is possible to classify sites in a number of ways according to their climate, source of flow, geology, land cover, network position, and valley landform classes. Median values for each water quality parameter from each site were calculated and then combined together to show the range of water quality within each REC classes. There is a considerable amount of intercorrelation among the different REC classes. For example, low elevation land is much more likely to have been developed into pasture than high elevation land. Therefore, significant differences among sites with different source of flow classes are likely to be due to differences in land cover rather than a direct effect of source of flow. Given the problems of intercorrelation among REC classes only comparisons among three REC classes; source of flow, land cover and network position (or stream order) are presented here. Statistical comparisons among REC classes for each water quality parameter were made using non-parametric Kruskal-Wallis tests, which are not influenced by non-normal data distributions.

Significant differences among source of flow classes were found for pH, total nitrogen, nitrate nitrogen, ammonium nitrogen, dissolved reactive phosphorus, total phosphorus, *E. coli*, water clarity, and turbidity. Sites draining low elevation land had higher concentrations of TN, NO_3-N, NH_4-N, DRP, TP, *E. coli*, and suspended sediments than sites draining hill country, mountains or flowing from a lake (Figure 16*). As mentioned above, these differences are probably due to differences in land cover rather than a direct effect of source of flow.

Significant differences were also found among the land cover classes for dissolved oxygen, pH, TN, NO_3-N, NH_4-N, DRP, TP, *E. coli*, clarity, turbidity, and suspended sediments. Concentrations of nutrients, *E. coli* and suspended sediment at sites classified as having pastoral land cover were higher than at sites with indigenous forest or exotic forest land cover. Similarly, water clarity was lower at pastoral sites than in forested sites. The one stream classified as being urban (Watercress Creek) appeared to be similar to the pastoral streams in terms of water quality but had lower oxygen concentrations and pH than sites in the other classes (Figure 17). The effects of land use on water quality are widely recognised and the results of this review are consistent with earlier nationwide studies of water quality patterns (Larned et al., 2004).

Oxygen saturation, water clarity, turbidity and the concentrations of TN, NO_3-N, DRP, and TP varied significantly among REC stream order classes. Oxygen saturation was lowest in first order streams, while concentrations of nutrients tended to be highest in the smaller streams (Figure 18). This result is somewhat contrary to the perception that small headwater streams are generally more healthy than larger lowland rivers. However, this result is related to the high proportion of small streams in the sampling programme which drain areas that are heavily developed (e.g., Reservoir Ck, Watercress Ck). The large rivers in the Tasman District generally have good water quality, probably due to the fact that much of their flow originates from areas of indigenous forest and thus run-off from developed lowland tributaries is diluted.

*Interpretation of Box Plots



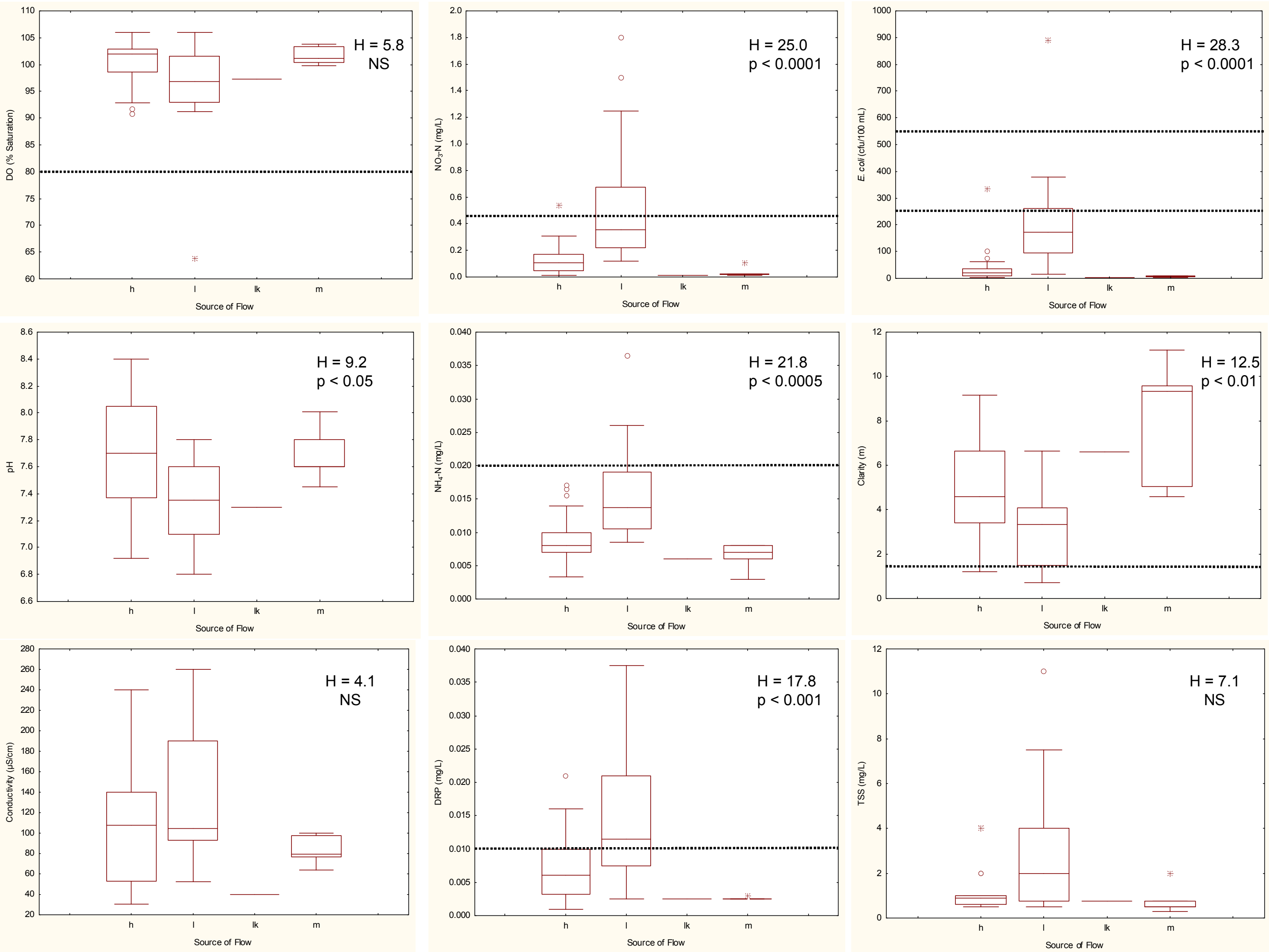


Figure 16 Comparison of median water quality parameters among REC Source of flow classes. h = hill country, l = low elevation, lk = lake, m = mountain. H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate.

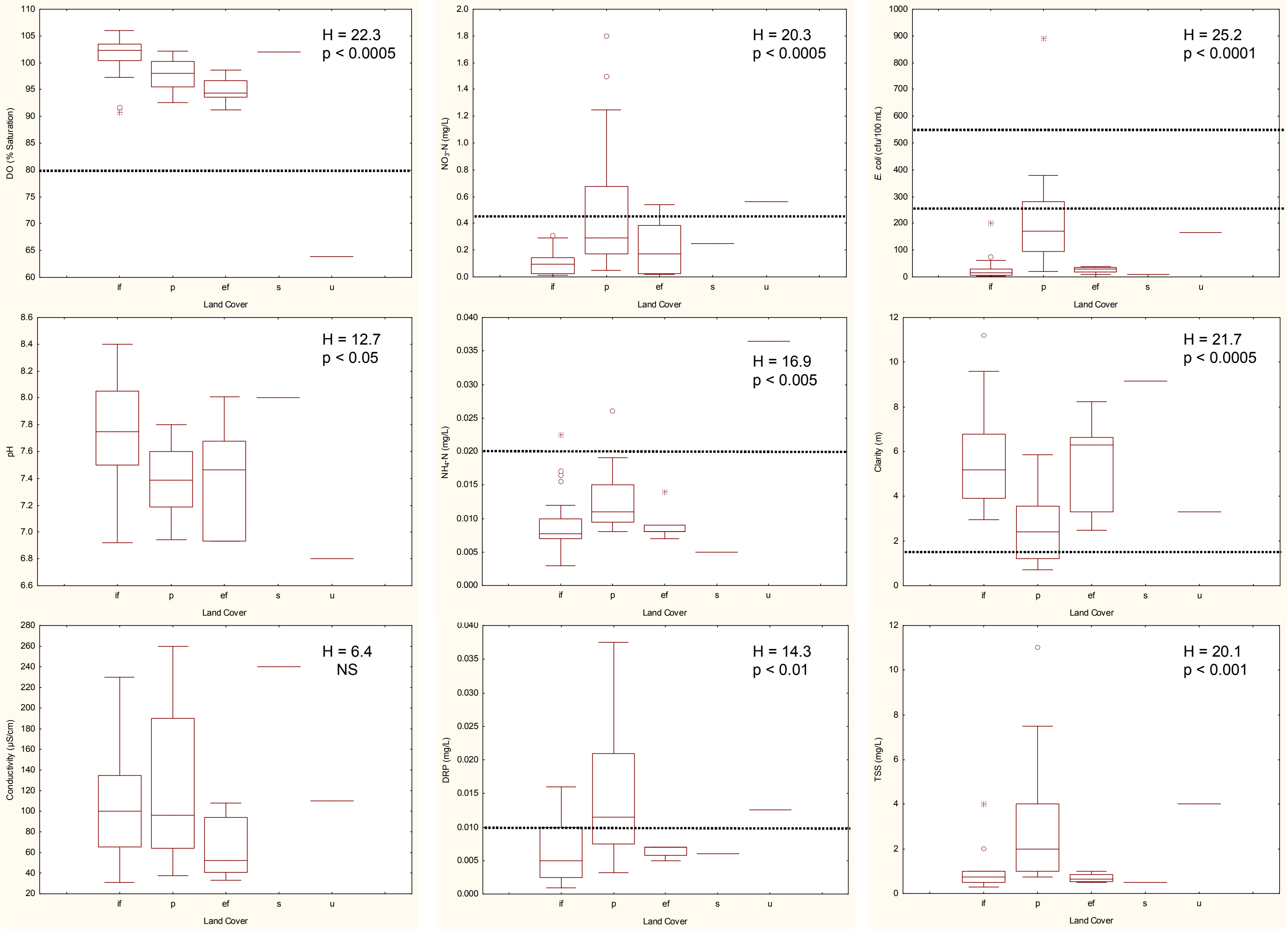


Figure 17 Comparison of median water quality parameters among REC Land cover classes. if = indigenous forest, p = pasture, ef = exotic forest, s = scrub, u = urban . H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate.

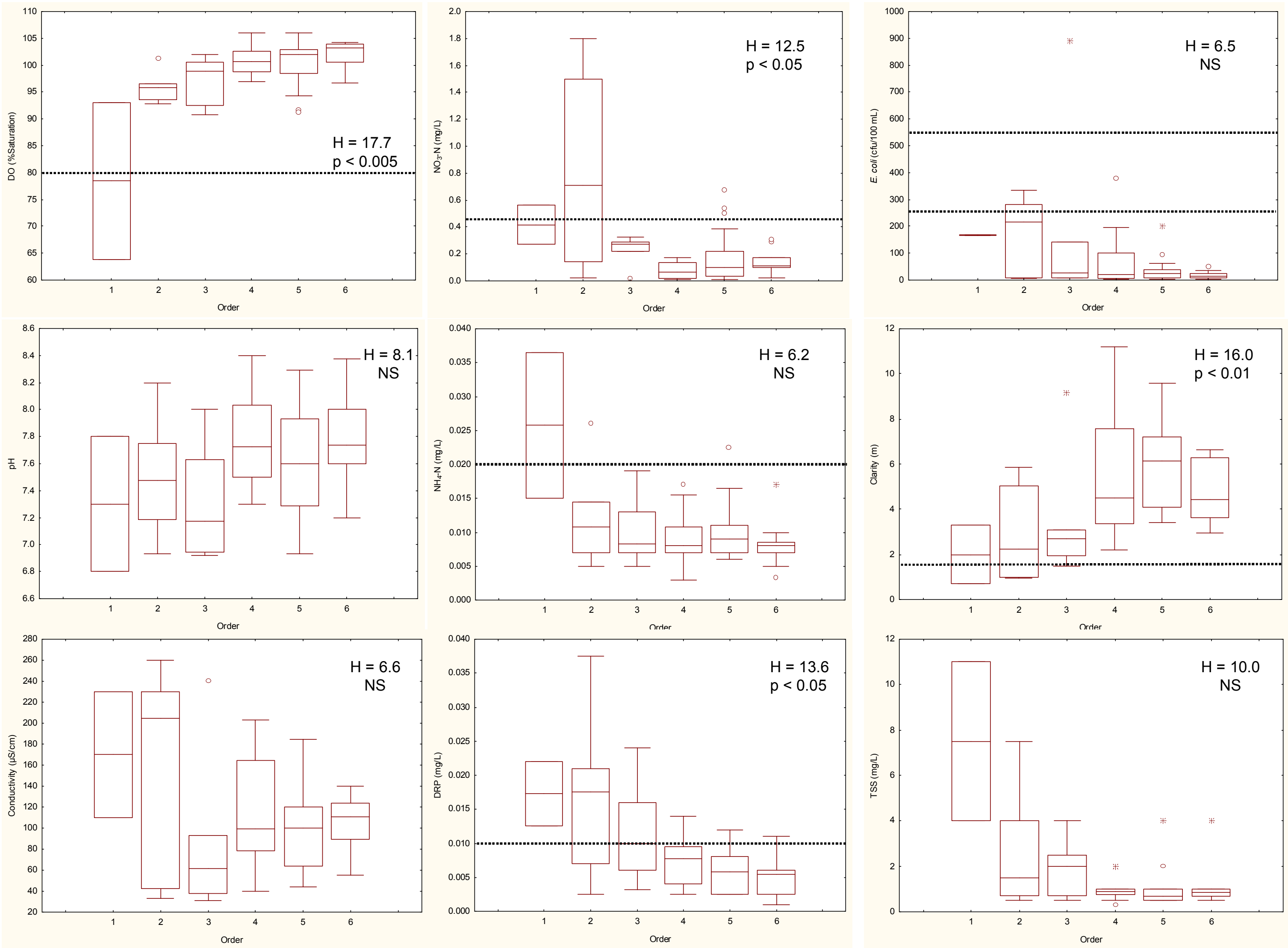


Figure 18 Comparison of median water quality parameters among REC stream order classes. Two first order streams join to form a second order stream, two second order streams join to form a third order stream etc. H-statistics and p-values from the Kruskal-Wallis tests are shown for each water quality parameter. Water quality guidelines are shown with dotted lines where appropriate.

3.4 Water Temperature

Temperature loggers (Onset StowAway Tidbit or TruTrack TH-R) have been deployed at 23 sites in the Motueka Catchment as part of the ICM programme. A logger has also been deployed in the lower reaches of the Owen River as part of Cawthron's backcountry fishery research. These loggers were programmed to record temperature every hour and operated from at least March 2001 to February 2002. An example of the full temperature record at three contrasting sites is shown in Figure 19. The Motupiko Rv at Christies site experienced very warm temperatures in summer and very cold temperatures in winter. The Motueka Rv at Gorge site had similar cold temperatures in the winter but water temperatures in the summer were much cooler than in the Motupiko Rv. The Graham Rv drains marble terrain and thus much of the water spends time underground before flowing down the river. Therefore, temperatures at this site remained relatively constant throughout the year, with cool water temperatures in the summer and relatively warm temperatures in the winter. It is also worth noting the large daily fluctuations in temperature at the Motupiko Rv at Christies site in the summer, compared with the relatively small daily variations in the Graham River.

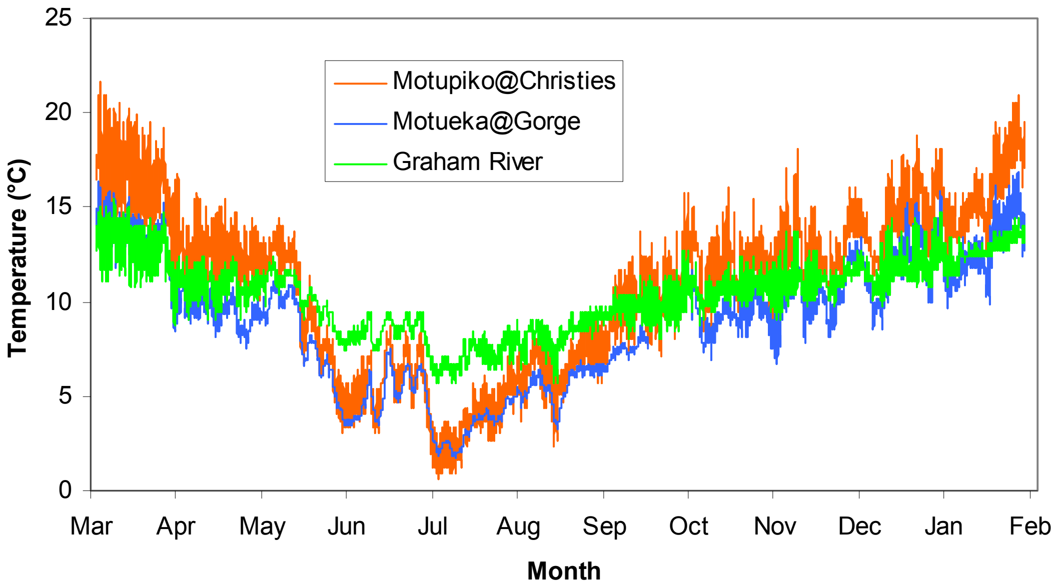


Figure 19 Yearly changes in water temperature at three contrasting sites in the Motueka River catchment

The main concerns with water temperature are the effects of high temperatures on aquatic life. Some species will only tolerate relatively cool water and may become stressed or die if temperatures become too high. For example, laboratory studies indicate that brown trout growth is optimal at 13°C (Elliott 1994). However, trout will cease feeding once temperatures climb above 19°C and they will begin to die once temperatures climb above 25°C for a sustained period (Elliott, 1994; Jowett, 1997). Trout cannot tolerate temperatures above 30°C for even a short period.

Quinn et al. (1994) examined the temperature tolerances of 12 types of freshwater invertebrates and found that LT_{50} values (i.e. the temperature at which 50% of animals died after 96 hours) under constant temperature conditions ranged from 22.6°C to 32.4°C. New Zealands' most common mayfly, *Deleatidium,* was the most sensitive species tested. Cox and Rutherford (2000) extended this work and considered the influence of daily temperature fluctuations on temperature tolerances. They found that LT_{50} values derived at constant temperatures could be compared with values halfway between the daily mean and daily maximum. They also suggest that a safety margin of 3°C should be used when setting an acceptable temperature for protecting a particular species. Therefore, in this report the criterion distinguishing acceptable and unacceptable temperatures has been set at 19.6°C (*i.e.* the LT_{50} for *Deleatidium* [22.6°C] minus a 3°C safety margin).

Since high temperatures are likely to be a problem only over the summer months, temperature data from the two month period over summer (15 December – 15 February) was used for the analysis of temperature patterns. The temperature value halfway between the daily mean and daily maximum was calculated at each site on each day during this two month period. The proportion of this summer period when this statistic was above or below the acceptable temperature criteria is shown in Figure 20.

Eleven of the 23 sites never exceeded the temperature criterion for protecting ecosystem health (Young et al, *in press*; Figure 20). The most regular temperature exceedances were in Waiwhero Ck (35% of the two month period), Tadmor Rv (27%), Little Sydney Ck (24%) and Motueka Rv at Woodmans Bend (18%). The effects of cool tributaries on water temperatures in the Motueka River are shown in the middle offset box (Figure 20). Temperatures exceeded the criterion occasionally in the Motueka Rv at Woodstock, but the cool waters from the Pearse and Graham rivers prevented the criterion from being exceeded in the Motueka Rv downstream of the Graham River. The effects of land use are demonstrated in the bottom offset box (Figure 20). Graham Stm and Hunter Ck are heavily shaded by pine forest and native forest respectively, and temperatures did not exceed the criterion during the recording period. However, the neighbouring Kikiwa Ck site with similar source of flow, flow rate, geology, network position and landform, drains pastoral land and there is little shading. The temperature criterion was often exceeded at this site (Figure 20). Thermal buffering in sites draining marble geology was due to strong connections to groundwater. Daily amplitude and rate of temperature change were found to be similar across all geologies for the same land cover. Stream temperature at small stream sites were more strongly influenced by land cover. Land cover also affects flow, and in pasture catchments that are unshaded, this can lead to even greater temperatures. A change in land use from pasture to pine forest in a Moutere gravel catchment caused the period without flow to increase from two to five months (Fahey et al 2004). However, shading from pine forest resulted in more moderate temperatures.

In addition to the study above, a temperature logger were placed in Reservoir Ck at Salisbury Road. This recorded a maximum of 28°C on 4 February 2005. Subsequently two further loggers were placed upstream at the Marlborough Cres site. The difference between the daily mean and daily maximum at these sites from 24 February to 24 March was: Salisbury Road: 21.5°C, Kareti Drive 21.5°C and Marlborough Crescent 17.5°C. The Kareti Drive site showed the highest temperatures (maximums consistently 1-2 degrees higher than Salisbury Road but overnight-lows were regularly 3°C lower). The higher maximums could be due to the heat generated from the long length of unshaded rock armouring in the bed and banks upstream of this site and high concentrations of suspended solids due to earthworks upstream. The relatively high overnight-low at the Salisbury Road site may be higher due to the Templemore Pond upstream.

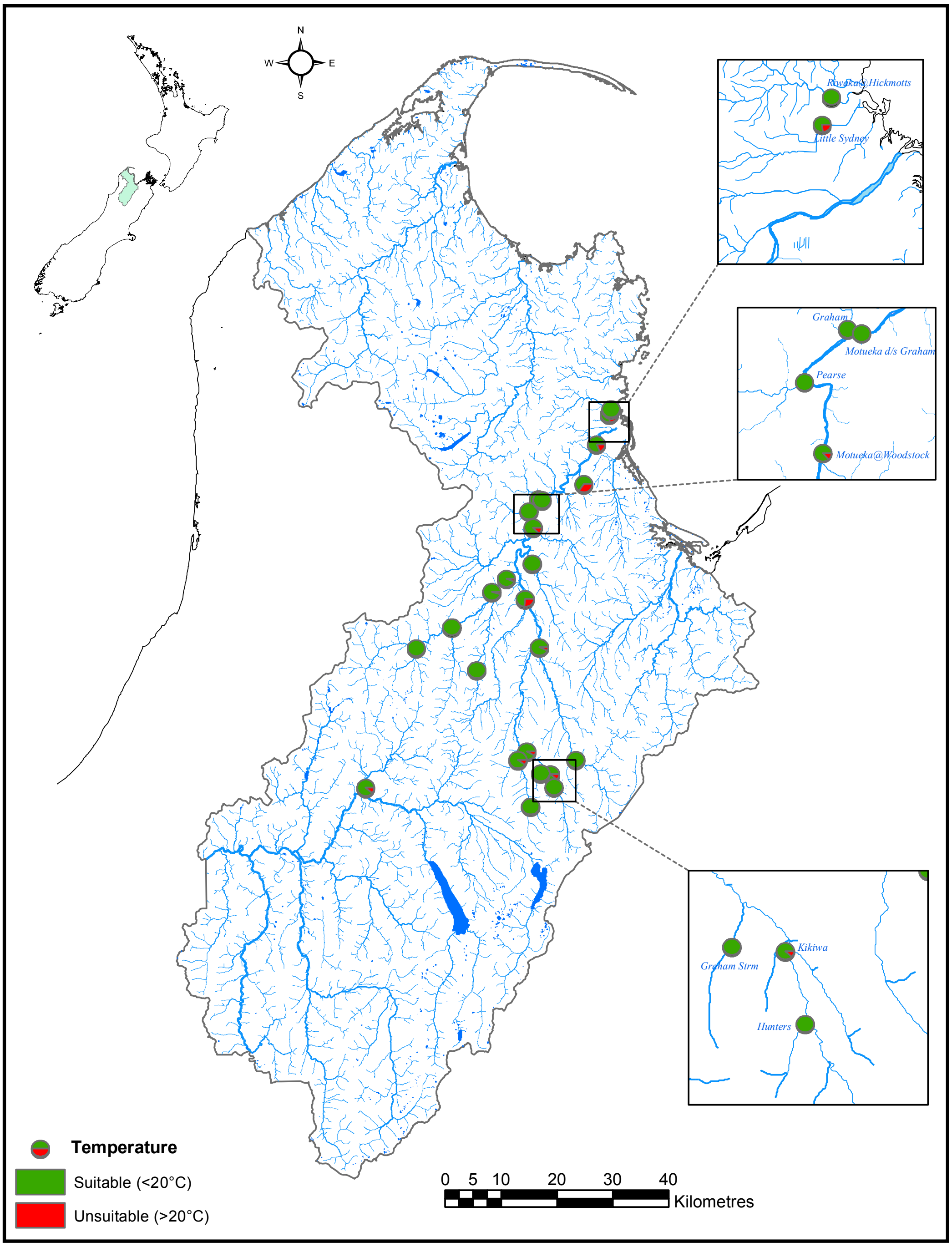


Figure 20 Proportion of the summer period when temperature measurements halfway between the daily mean and daily maximum met or exceeded criteria for ecosystem health

3.5 Trends at National River Water Quality Network Sites

Water quality samples have been collected monthly at the National River Water Quality Network sites since January 1989 and thus provide a sufficient number of data points for trends to be calculated. Trends were determined using nonparametric Seasonal Kendall trend statistics, which compute the slope (or magnitude) and significance of any trends in the data. As the name suggests, seasonal variations in water quality are accounted for by this technique. These statistics have been used previously in New Zealand to analyse trends in the records from the National River Water Quality Network and are described fully in Smith et al. (1996). Following Vant and Wilson (1998), a Microsoft Excel spreadsheet was used to calculate the slopes and significance of any trends in the data.

Analyses were initially conducted on the raw data. Some water quality variables are strongly affected by varying flows, therefore it was appropriate to adjust data according to the flows when it was collected. This "flow adjustment" procedure involved the determination of the relationship between flow and the water quality variable, this giving the expected value corresponding to the flow at the time of sampling. The difference between this expected value and the measured value gave the flow-dependent residual. The sum of this residual and the median value of the raw data gave the flow adjusted value of the variable. Flow adjustment was only conducted on variables that displayed clear relationships with flow.

The concentrations of ammonium nitrogen showed significant declines at all three NRWQN sites over the course of the record (Figure 21, Table 3). These declines were all relatively large, with changes in relative slope of between 4.4-10.9% per year of the median values (Table 3). Total nitrogen concentrations increased significantly at all three sites over the record, with changes in relative slope of around 2% per year of the median values at each site (Table 3). The fact that these changes have been observed at all three sites including Motueka Rv at Gorge (which is not influenced by human land use) perhaps indicates that these trends are the result of long-term changes in climate rather than changes in land management.

Nitrate nitrogen concentrations increased at the Motueka Rv at Woodstock site over the record (Figure 22, Table 3). No changes in nitrate concentrations were observed at the other two NRWQN sites, so it is possible that this increase is due to changes in land management within the Motueka River catchment.

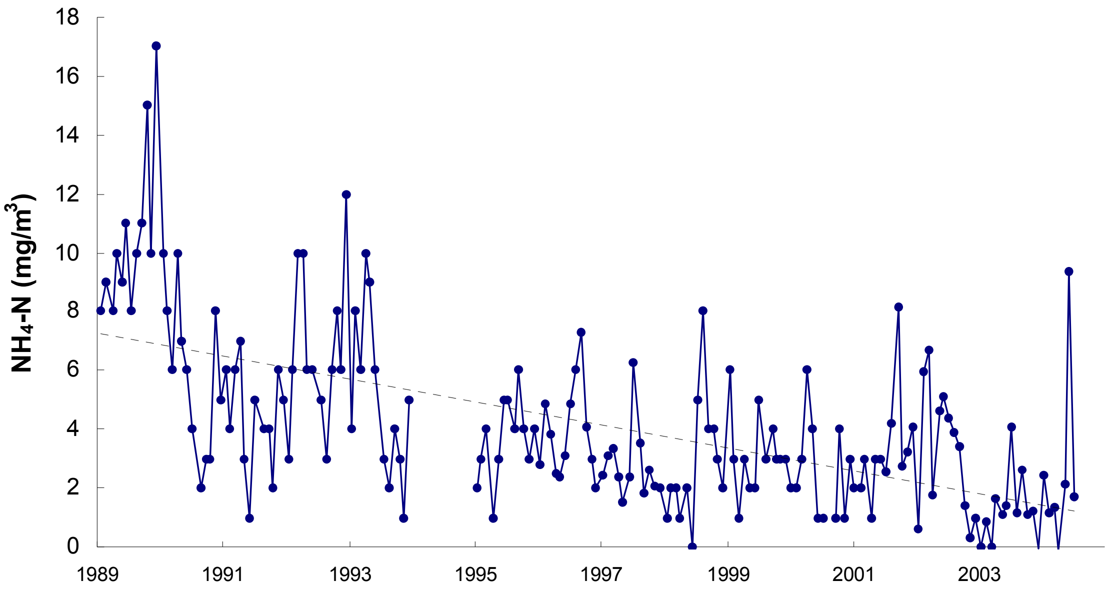


Figure 21 Decline in ammonium nitrogen concentration at the Buller Rv at Longford site

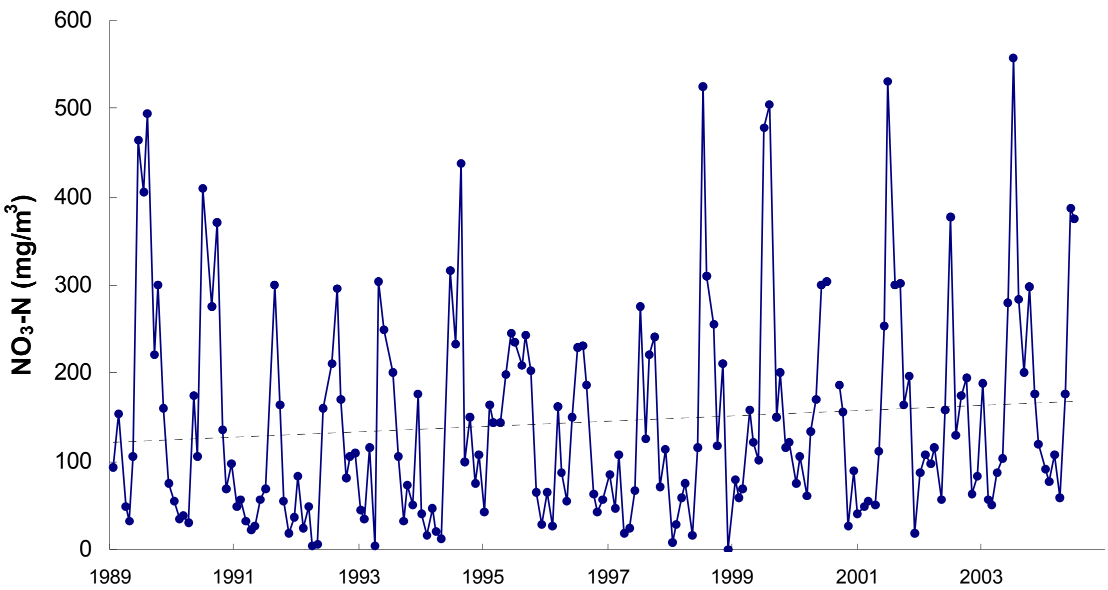


Figure 22 Increase in nitrate nitrogen concentration at the Motueka Rv at Woodstock site

Table 3 Significant ($p < 5\%$) trends in water quality parameters at the NRWQN sites

Site	WQ Parameter	Slope	Relative slope	p-value (%)
Motueka Rv @ Woodstock (NN1)	Ammonium nitrogen	-0.20	-4.36	<0.001
	Total Nitrogen	3.8	1.97	0.363
	Nitrate nitrogen	2.81	2.61	0.148
	Conductivity*	0.24	0.21	2.3
Motueka Rv @ Gorge (NN2)	Ammonium nitrogen	-0.22	-7.58	<0.001
	Total nitrogen	1.01	1.98	1.4
	Dissolved oxygen (% Sat.)	0.06	0.06	0.039
	Dissolved reactive phosphorus	0.037	1.42	0.35
	Total phosphorus	0.062	1.54	0.19
	Clarity*	0.16	1.55	0.64
Buller Rv @ Longford (NN5)	Ammonium nitrogen	-0.35	-10.90	<0.001
	Total nitrogen	1.72	2.2	0.007
	Clarity*	0.1286	3.52	<0.001

The slope in Table 3 indicates the size of the trend in water quality units per year, while the relative slope indicates the trend per year as a percentage of the median value for that parameter. The significance of the trends is shown with the p-value. Parameters that were flow adjusted before analysis are shown with an asterisk.

Water clarity increased significantly over the length of the data record at the Motueka Rv at Gorge and Buller Rv at Longford sites (Table 3), and there was also an indication of increasing water clarity at the Motueka Rv at Woodstock site, although the slope was not quite significant at the 5% level (slope 0.047, relative slope 1.24, p = 7.5%). Improvements in water clarity have been found at many other sites throughout New Zealand (Scarsbrook et al., 2003; Larned et al., 2004) and have been related to long-term influences of climate rather than improvements in land management (Scarsbrook et al., 2003).

An increase in conductivity has been observed at many sites throughout the country (Larned et al., 2004) and was also apparent at the Motueka Rv at Woodstock site. However, no significant trends in conductivity were observed at the Motueka Rv at Gorge or Buller Rv at Longford sites.

Significant increases in dissolved oxygen saturation and the concentrations of dissolved reactive phosphorus and total phosphorus were observed at the Motueka Rv at Gorge site (Table 3). The relative slope of the trend in dissolved oxygen saturation was very small (0.06) and therefore is ecologically insignificant. The cause of the increase in dissolved reactive and total phosphate concentrations at this site are unknown, but presumably related to climatic factors, since the catchment upstream of this site is largely undisturbed.

4 MACROINVERTEBRATES

Figures showing the average and range of various macroinvertebrate indices are shown in Appendix 4. These figures are relatively detailed and require knowledge of the sites to interpret District-wide patterns. To enable easier interpretation of the macroinvertebrate data the results of the sampling have been plotted onto maps of the District (Figures 23-26).

The condition of the aquatic ecology at a site was assessed using all relevant indices listed in Table 4.

Table 4: Criteria for water quality based on macro-invertebrate indices

Macro-invertebrate Index	Poor	Average	Good	Excellent
MCI	< 100	100 – 110	110 – 120	> 120
SQMCI	< 4.2	4.2 – 5.0	5.0 – 6.0	> 6.0
Mean number of species	<9	9 – 15	15 – 24	> 24
Total species	< 10	15 – 20	20 – 30	>30
Total EPT species	< 5	9 – 15	15 – 20	> 20

Taxa richness is a coarse indicator of river ecosystem health and was fairly variable throughout the District (Figure 23). Some of the sites with low taxa richness (Watercress Ck u/s factory, Reservoir Ck) also had poor water quality, which may have been responsible for the low taxa richness. However, very low taxa richness was also found during the single sampling occasion at sites (Motueka right branch, Ellis Stm, Porters Ck) located near the headwaters of the Motueka River, perhaps due to the effects of the ultramafic geology found in the Red Hills area. Very low taxa richness has also been consistently found in the Aorere Rv at Devils Boots and in the Takaka Rv at Kotinga. It is not known why these sites have such low taxa richness.

An ecological study of the Takaka River, its tributaries and the Motupipi River was carried out in April 1998 (MacGibbon, 1999). Macroinvertebrate populations were healthy at most mainstem and tributary sites, indicating clean waters or low levels of organic enrichment. The Paynes Ford site recorded impoverished aquatic faunal populations.

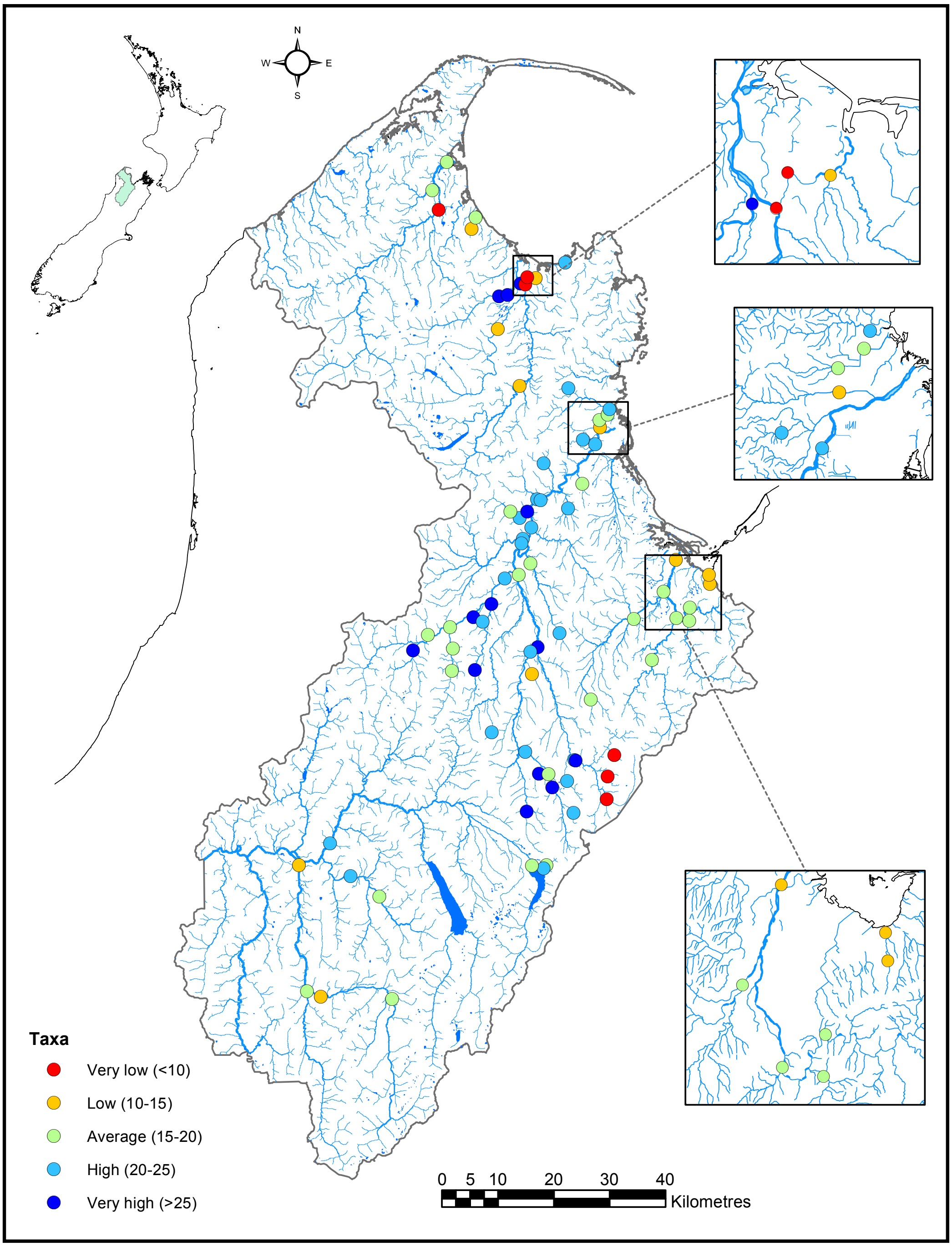


Figure 23 Taxa richness or number of types of invertebrates typically found at each site

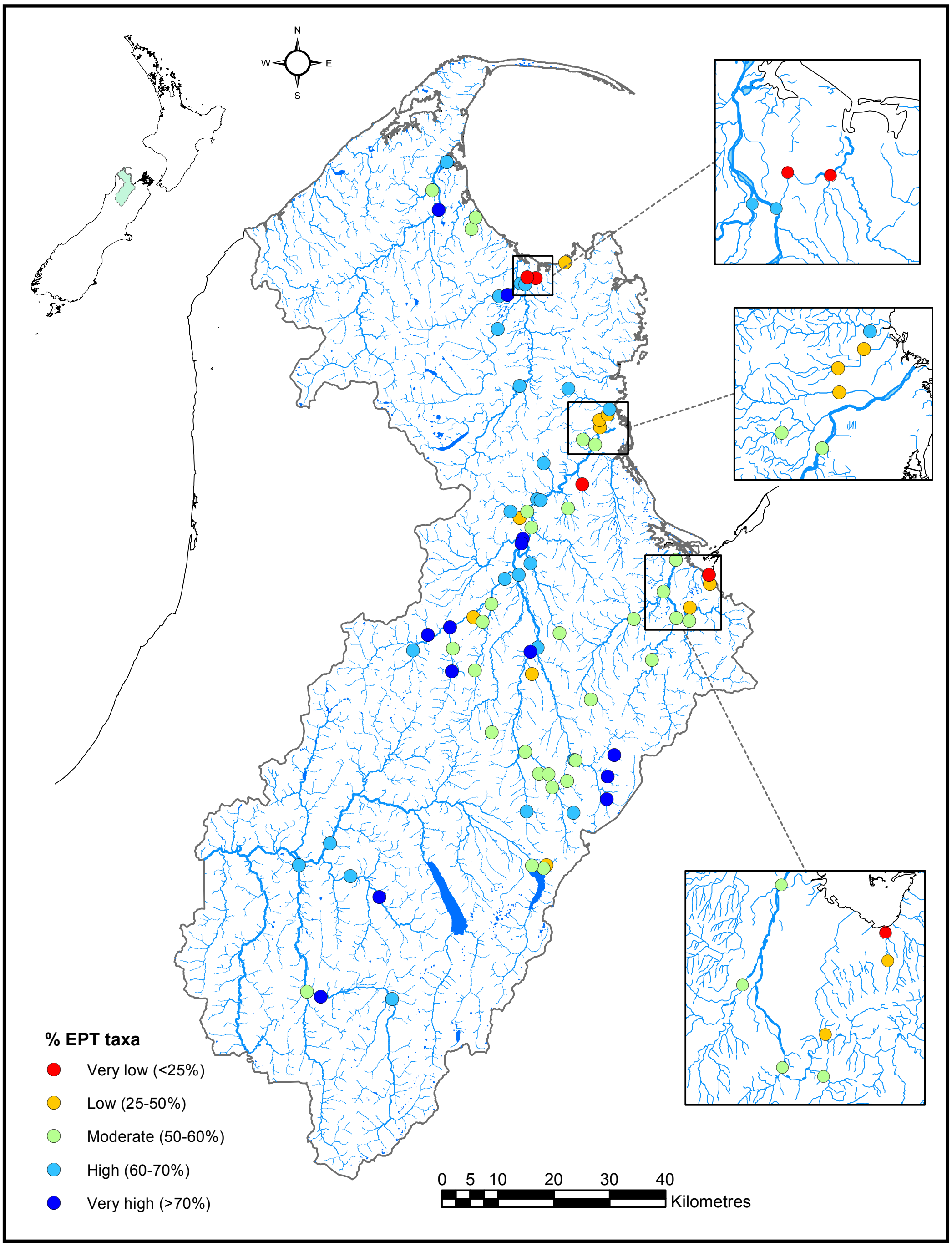


Figure 24 Percentage of taxa that belong to the sensitive mayfly (*Ephemeroptera*), stonefly (*Plecoptera*) and caddis fly (*Trichoptera*) groups

Mayflies, stoneflies and caddis flies tend to be sensitive to environmental degradation, therefore the percentage of the taxa at a site comprising these groups provides a relatively sensitive indicator of river ecosystem health. Sites with very low percentages of these EPT taxa (Watercress Ck, Motupipi Rv, Waiwhero Ck, Reservoir Ck; Figure 24) were also identified as having relatively poor water quality. In contrast, sites in the upper parts of most catchments tended to have moderate to high percentages of EPT taxa, indicating good ecosystem health.

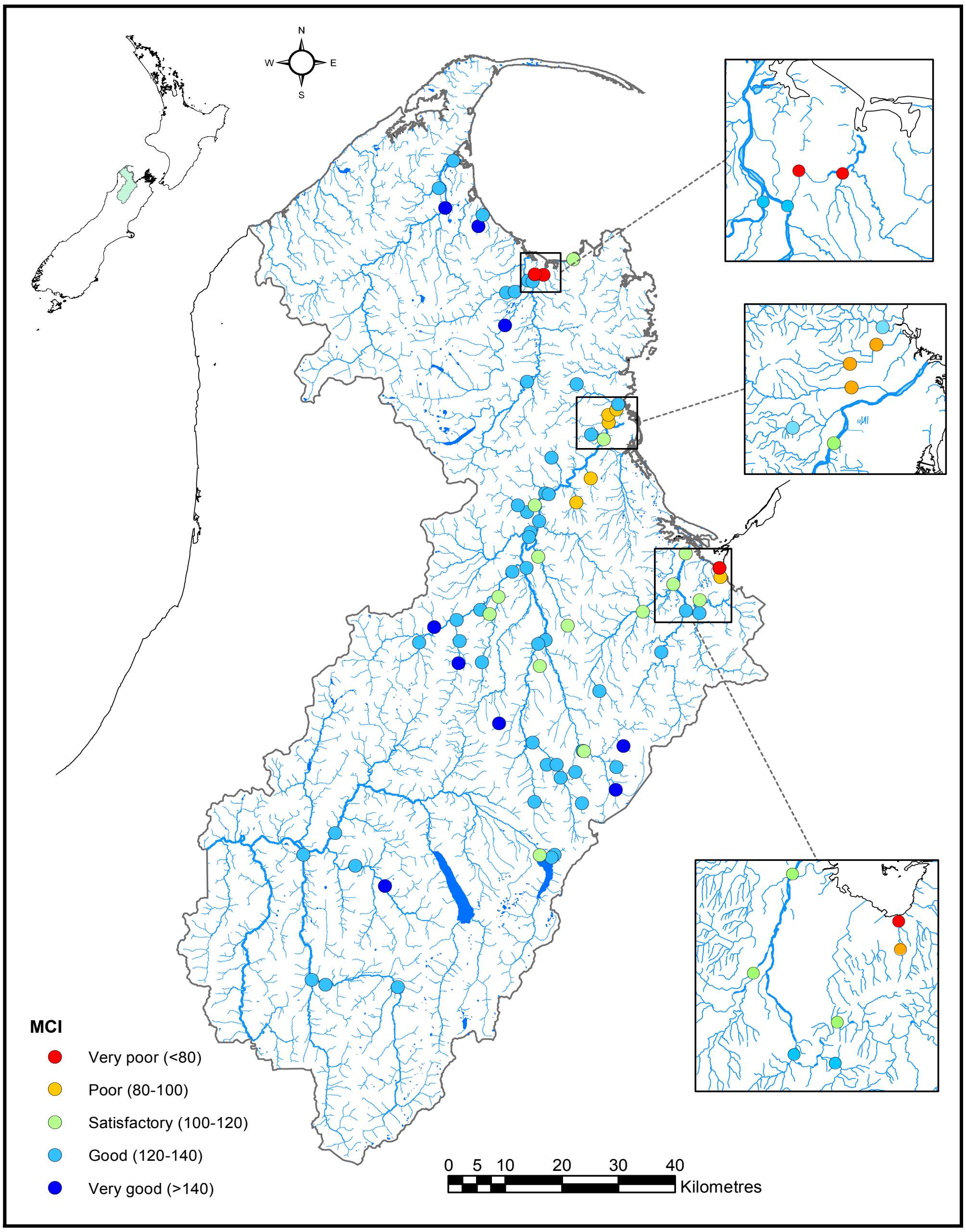


Figure 25 Average macroinvertebrate community index (MCI) scores at each site
This scoring system is based on the presence or absence of particular types of macroinvertebrates.

The macroinvertebrate community index (MCI) and its semi-quantitative variant (SQMCI) are more refined indicators of river ecosystem health and show very similar patterns throughout the Tasman District (Figures 25 and 26). Sites with low MCI scores (Watercress Ck, Motupipi Rv, Reservoir Ck) typically have poor water quality, which has apparently had an adverse effect on stream life. Low SQMCI scores were also seen in the Rosedale Ck and Waiwhero Ck at cemetery sites (Figure 26). Relatively low MCI and SQMCI scores were also reported from Brooklyn Stm and Little Sydney Ck, which are also both small lowland tributaries draining developed land.

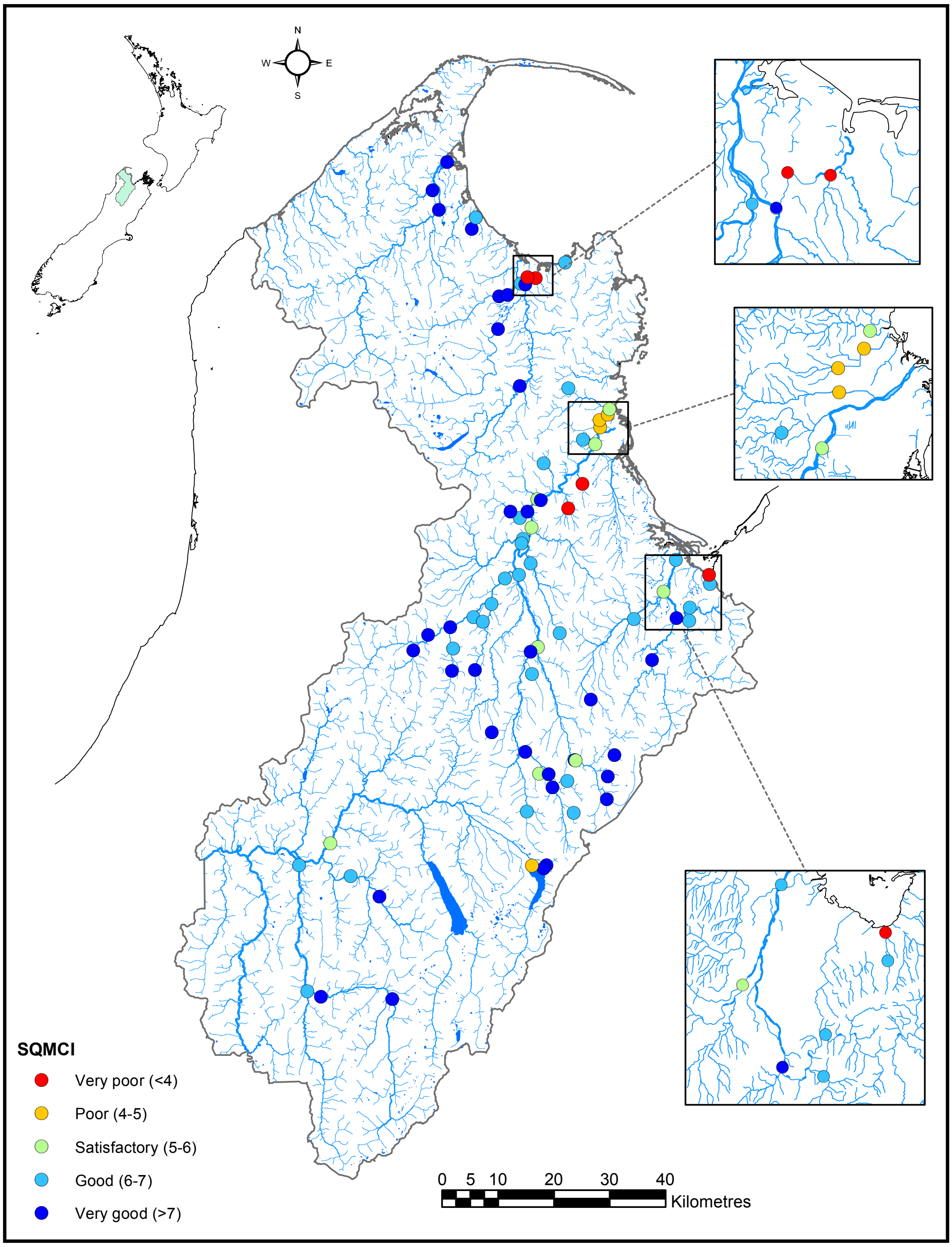


Figure 26 Average semi-quantitative macroinvertebrate community index (SQMCI) scores at each site. This index is based on the presence/absence and abundance of particular types of macroinvertebrates found at each site.

Sites in the inland parts of the District appeared to have healthy stream communities. The low SQMCI score that is reported for the Buller Rv at Lake site is typical of lake outlets and should not be interpreted as indicating poor ecosystem health (Figure 26).

4.1 Site Groupings

Non-metric multidimensional scaling (NMDS) was used to investigate the similarity of sites based on the macroinvertebrate data. Relative abundance data from the 2001, 2002 and 2003 sampling periods was used in the analysis. Relative abundance codes were converted to numerical values corresponding to the lowest values of each class (e.g., abundant = 20). Similarity between sites was calculated using Bray-Curtis distance measure. The NMDS analysis plots samples in two dimensional space such that samples with similar invertebrate communities are plotted close together, while dissimilar samples are plotted far apart (Figure 27). The accuracy of the representation of similarities among sites is represented by the stress value, which in this case was 0.24.

The arrangement of sites on the macroinvertebrate NMDS ordination (Figure 27) shows considerable similarity to the ordination of sites based on water quality (Figure 15) suggesting that water quality is an important factor controlling macroinvertebrate community composition. Most of the “red” poor water quality sites were towards the centre/left of the macroinvertebrate ordination and reasonably well separated from the other sites. This was particularly the case for Little Sydney Ck, Watercress Ck, Motupipi Rv, Waiwhero Ck, Reservoir Ck at d/s Salisbury Road and Winter Ck (Figure 27). The main exceptions to this were Reservoir Ck at u/s Marlborough Crescent and Kikiwa Stm, which were both plotted towards the centre of the macroinvertebrate ordination in 2003 and towards the right of the macroinvertebrate ordination in 2001 and 2002, indicating that the macroinvertebrate communities found at these sites were similar to those at the “green” sites with high water quality (Figure 27).

The “yellow” sites were considered to have intermediate water quality (Section 3.2) and were also plotted towards the centre/right of the macroinvertebrate ordination, supporting the suggestion that these sites are of intermediate health.

The majority of the “green” high water quality sites were plotted at the far right-hand side of the macroinvertebrate ordination and presumably represent high-quality macroinvertebrate communities. Samples collected from the Buller Rv at Lake site were plotted in the centre of the macroinvertebrate ordination and probably reflect the fact that this is the only lake outlet invertebrate community sampled and not necessarily that the community there is impaired. Graham Stm was also considered to be a “green” site in terms of water quality but was consistently plotted in the centre of the macroinvertebrate ordination, perhaps indicating some concerns with the macroinvertebrate community.

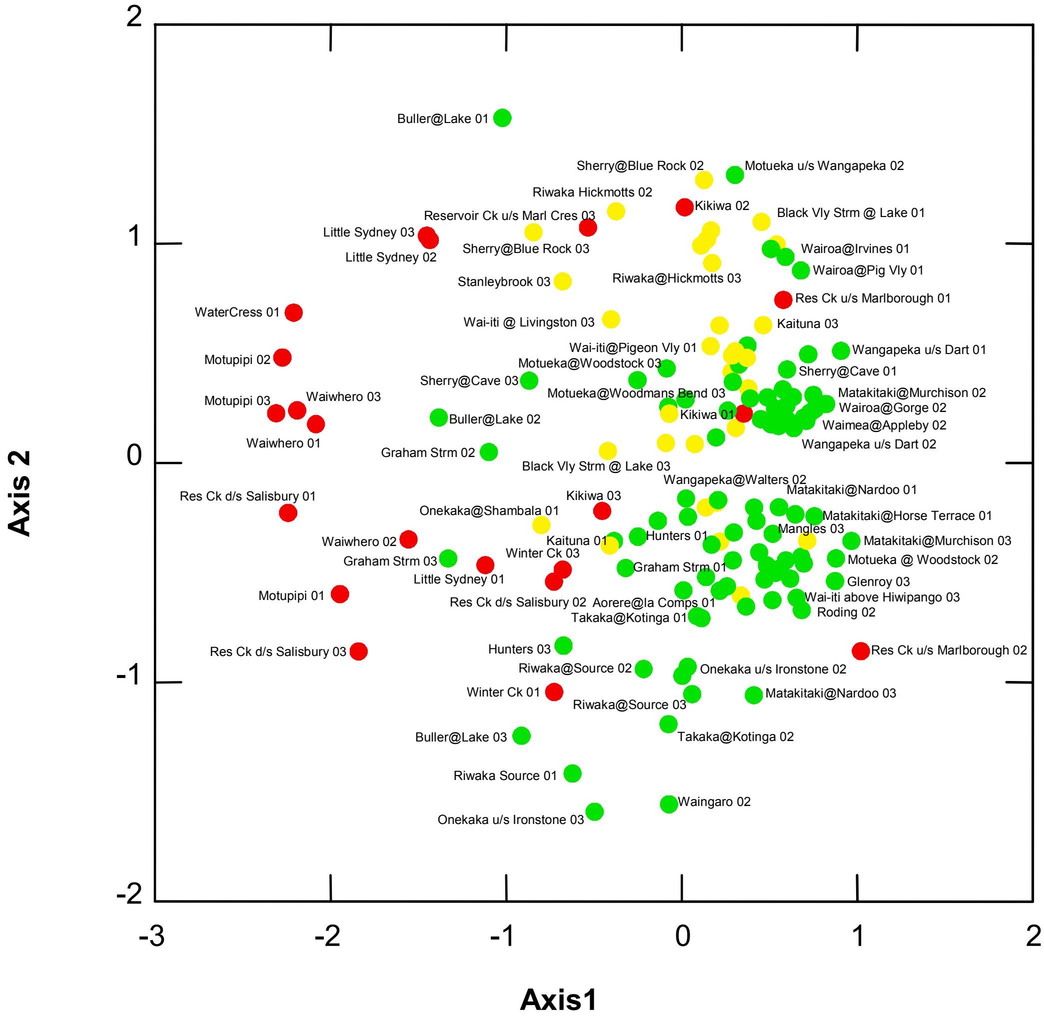


Figure 27 Non-metric multi-dimensional scaling ordination plot showing the similarity of sites and sampling occasions based on the macroinvertebrate data. The sites are colour coded based upon the water quality classification in Section 3.2. The year when each sample was collected is indicated at the end of the site label.

4.2 REC Groupings

Significant differences among REC Source of flow classes were found for the more sensitive invertebrate indices % EPT, MCI and SQMCI (Figure 28). Scores were typically lower at sites draining lowland areas than at sites draining hill country or mountains. Mountain-fed streams had higher ranges of “number of taxa” (types of macroinvertebrates), probably due to greater natural disturbance from high flow events. The single lake outlet site had scores that were equivalent to the lowland sites, but as mentioned above this is typical for lake outlet sites and not an indication of poor health.

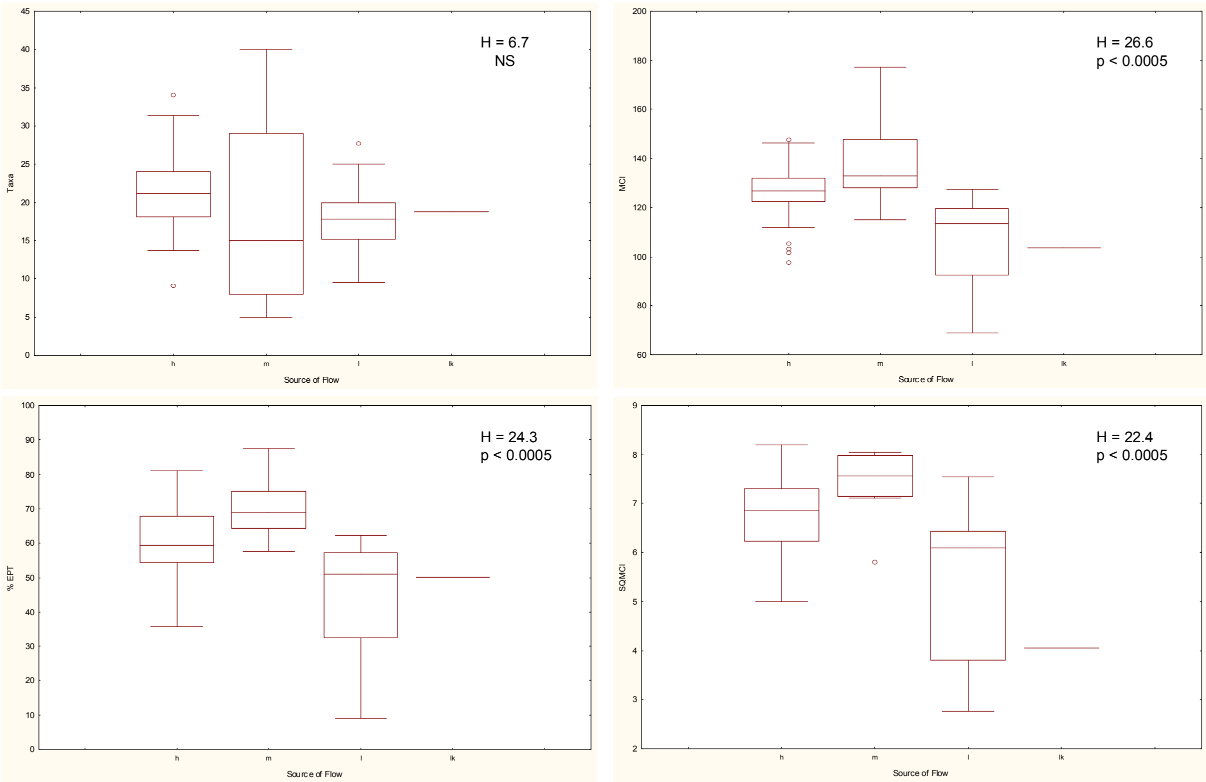


Figure 28 Comparison of average invertebrate indices among REC Source of flow classes. h = hill country, l = low elevation, lk = lake, m = mountain. H-statistics and p-values from Kruskal-Wallis tests are shown for each index.

There were also strong differences in invertebrate index scores among the REC land cover classes (Figure 29). The urban and tussock sites had low taxa richness compared with the other groups of sites, while the invertebrate community in the urban and pastoral sites had a lower percentage of EPT taxa (mayflies, stoneflies and caddis flies) than the other groups of sites. The MCI and SQMCI scores indicated relatively poor health in the urban stream (Watercress Ck) and in many of the pastoral streams, while stream health in the indigenous forest, exotic forest, tussock and scrub sites was generally high.

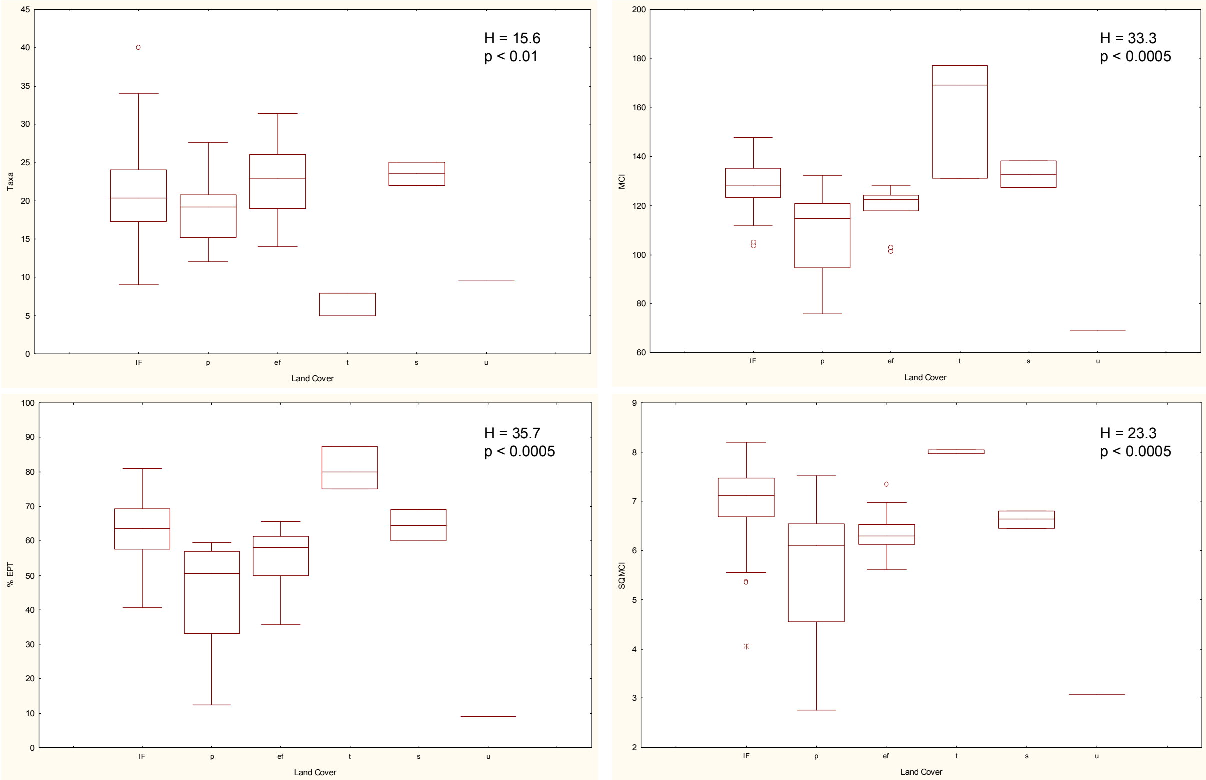


Figure 29 **Comparison of average invertebrate indices among REC land cover classes. if = indigenous forest, p = pasture, ef = exotic forest, t = tussock, s = scrub, u = urban . H-statistics and p-values from Kruskal-Wallis tests are shown for each index.**

There was little clear pattern in invertebrate indices among REC stream order classes (Figure 30). The percentage of EPT taxa was lower in first order streams than in the larger streams and rivers, and some of the lowest MCI and SQMCI scores were also observed in these small streams. This effect is probably not a direct effect of stream size, but rather an indirect effect of land use, since most of the first order sites that have been sampled are in heavily developed pastoral or urban areas.

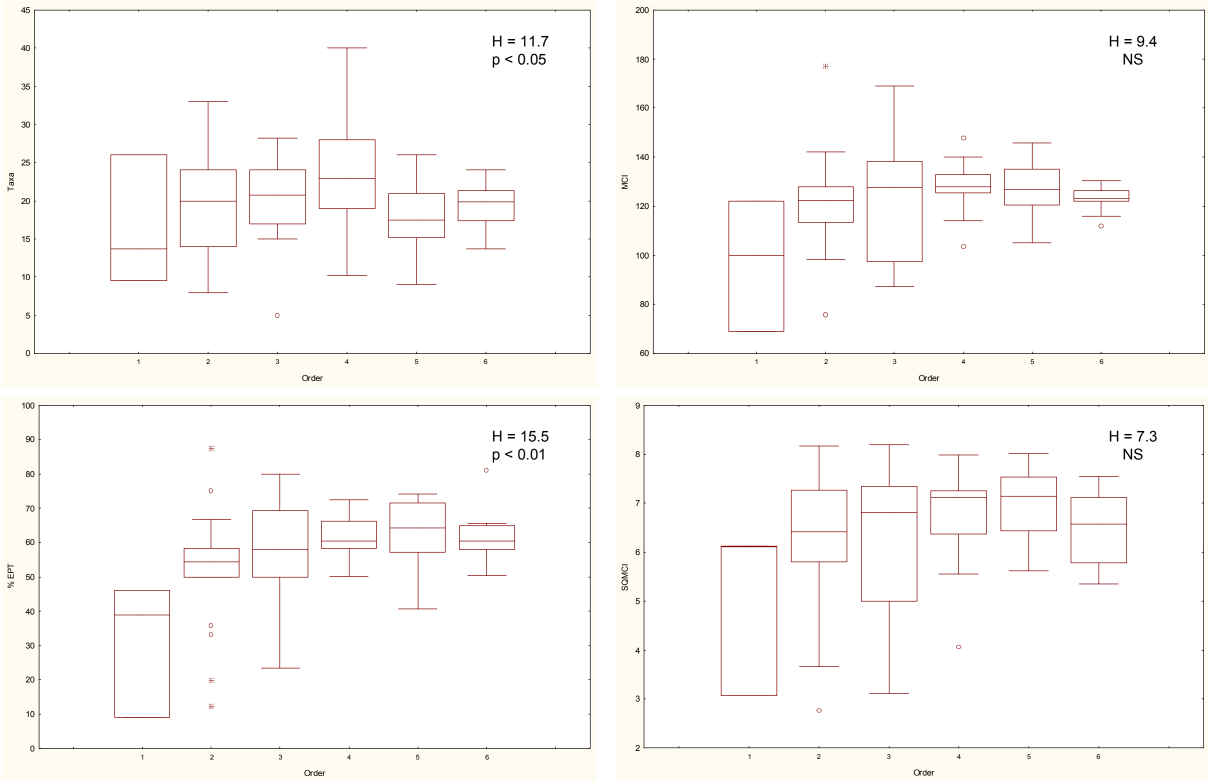


Figure 30 Comparison of average invertebrate indices among REC stream order classes. Two first order streams join to form a second order stream, two second order streams join to form a third order stream etc. H-statistics and p-values from Kruskal-Wallis tests are shown for each index.

4.3 Trends in Macroinvertebrate Data

Scarsbrook et al. (2000) reported trends in macroinvertebrate communities at the National River Water Quality Network (NRWQN) sites over the period from 1989 to 1996. For the Buller Rv at Longford site they found a decrease in taxa richness (i.e. number of types of macroinvertebrates) and a decrease in the number of sensitive EPT taxa, but an increase in the MCI. At the Motueka Rv at Woodstock site they found a decrease in the percentage of individual macroinvertebrates that were either mayflies, stoneflies or caddis flies (%EPT).

5 PERIPHYTON

A box plot of periphyton scores at sites throughout the Tasman District (Figure 30) shows that periphyton communities at most sites are indicative of good water quality, on the majority of sampling occasions. However, there are a number of exceptions. The Buller Rv at Lake Rotoiti outlet, Motopipi Rv at Reilly's Crossing, Reservoir Ck at Salisbury Road, Wairoa Rv at Clover Road and Watercress Ck at Dairy Factory are all notable for the large proportion of their periphyton samples that are indicative of lower water quality. There are also a number of "one-off" samples (shown as a "-" on Figure 30) that show relatively low periphyton scores, at least at the time of sampling (Figure 30). These sites are Takaka Rv at Paynes Ford, and a series of sites in the Waimea Rv catchment which were sampled during the 2001 drought (Waimea Rv at Challies Island and at Nursery, and the Wairoa Rv at WEIS Weir, Clover Rd and at its confluence with the Wai-iti Rv).

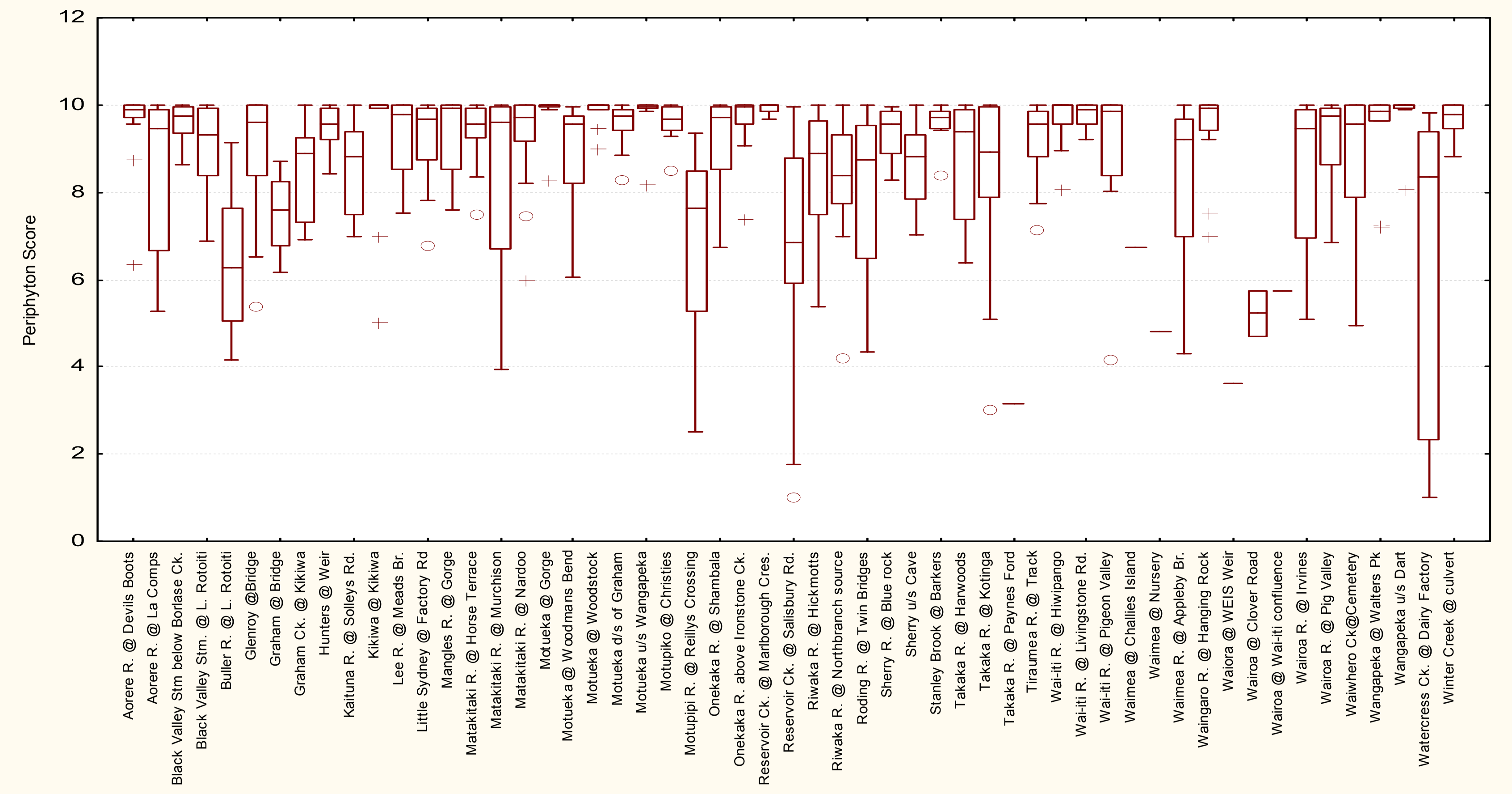


Figure 30a **Box plot of periphyton scores at monitoring sites in the Tasman District (See text for explanation of scores, scores range from 1-10, with 10 indicating high ecosystem health).**

Sites with frequently low periphyton scores are also evident in Figure 31, which provides a simple spatial overview of the way the periphyton indicator behaves over the Tasman District. The majority of sites that had a high proportion of their periphyton scores below a score of 8 also showed high levels of exceedance of guidelines for nutrient concentrations (Figures 7-10). These were mainly lowland streams, draining agricultural land. The exceptions to this were the Buller Rv at Lake Rotoiti site and the Wairoa Rv at Irvines site. The Buller Rv at Lake site probably owes its low periphyton scores to a highly stable flow regime, typical of lake outlets, allowing lower-scoring filamentous algae to establish. However, the reason why the Wairoa Rv at Irvines site should score so lowly, in the absence of high nutrient loads, is not obvious.

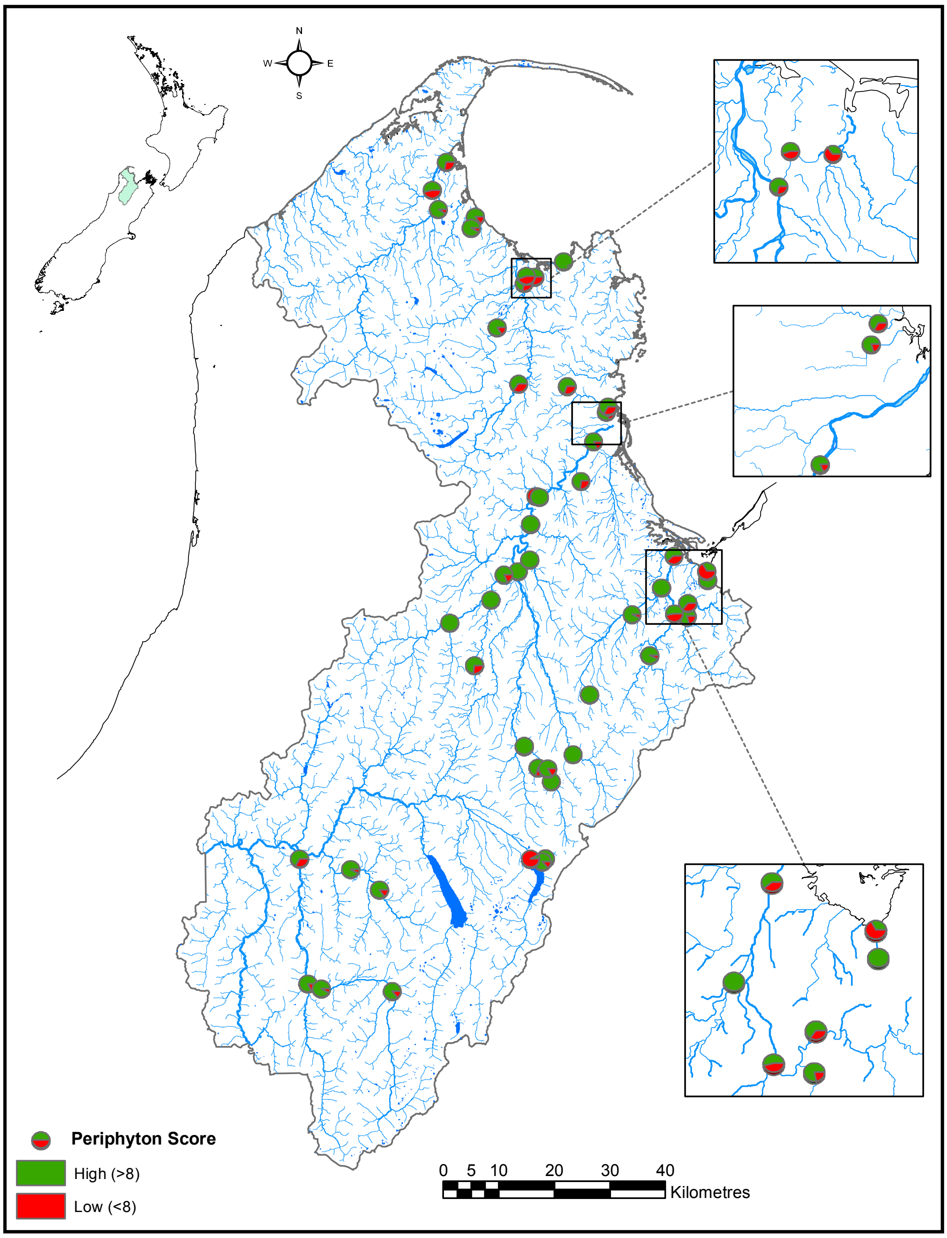


Figure 31 Proportion of samples for which the periphyton community indicator scores from each site that did, or did not, exceed a score of 8. (A score of 10 is the highest possible, indicating a healthy stream.)

Case Study – Lake Rotoiti

Sampling of Lake Rotoiti undertaken in 1999 (Smith, 1999) indicated that the lake is fully oxygenated and has low levels of nutrients, as would be expected for a lake that is virtually unaffected by human activities. Comparing these results with earlier investigations in 1976, 1990 and 1992-94 indicate that the quality of the lake environment has not changed significantly in the past 25 years.

Monitoring Black Valley Stm, the only waterway with any potential to affect water quality of the lake, has shown good water quality over the past five years. Nutrient concentrations in the stream were almost always within guidelines and the waterway was always suitable for contact recreation. Macroinvertebrate health was also very good.

6 DISCUSSION OF THE STATE OF TASMAN'S SURFACE WATER QUALITY

6.1 General

The lower reaches of the main rivers throughout the Tasman District are in relatively good condition compared with many of the other large rivers around the country (Larned et al., 2004). The relatively high proportion of indigenous forest in the catchments of large Tasman rivers means that inputs of pollutants from developed tributaries joining the river in the middle and lower reaches are diluted by a large volume of high quality water from upstream. Macroinvertebrate communities in the lower reaches of the main rivers are indicative of clean water or mild pollution (Boothroyd and Stark, 2000). High water temperatures in the summer, rather than chemical pollutants, may be responsible for the reduction in river health scores in the lower reaches of the main rivers (Young et al. in press).

Streams and rivers draining the higher altitude and undeveloped areas of the Tasman District have excellent water quality and support a diverse range of macroinvertebrates. Periphyton accumulation at these sites is minimal and is dominated by diatoms.

Throughout the Tasman District, small streams draining developed land (agriculture, urban, horticulture) are typically in poor condition, with low water clarity and high concentrations of nutrients and faecal indicator bacteria. In a few extreme situations, dissolved oxygen levels are low enough to harm aquatic life. Small streams draining developed land have macroinvertebrate communities indicative of moderate to severe pollution (Boothroyd and Stark, 2000). Periphyton accumulation in some of these streams is excessive and likely to cause nuisance to those people recreating in these areas.

Given the poor state of many small streams draining developed areas, restoration efforts should focus on trying to improve the quality of these systems. If improvements can be made, this will also lead to small cumulative improvements in the quality of the main rivers.

6.2 Pressure, State and Response in Relation to Various Resource Use Activities

This section highlights the monitoring and regulation issues relating to the more significant environmental pressures in Tasman District. For some pressures not enough data is available to make comment. This lack of data stems in part from the fact that not all pressures, for example fruit-growing, are represented in the Surface Water Quality Monitoring Programme.

6.2.1 Sewage Discharges from Municipal Sewerage Systems

Pressure

Raw sewage or poorly treated sewage discharges can contain high concentrations of bacteria that may cause disease in humans and livestock, and ammonia, which is toxic to aquatic life. Ammonia and other contaminants in sewage effluent can reduce the oxygen in the receiving water and cause suffocation of organisms living in this environment. Discharges of raw sewage are of particularly high threat to human health and may cause ecological damage due to high concentrations of ammonia.

The sewage from all towns in Tasman District is treated with plants at the following locations: Collingwood, Takaka, Upper Takaka, Motueka (also services Riwaka to Kaiteriteri), Tapawera, Murchison, St Arnaud and the regional sewage facility at Bell Island (serves Wakefield, Brightwater, Hope, Mapua, Richmond and a large part of Nelson). These treatment plants generally employ oxidation ponds, the performance of which may be affected by variable effluent loading rates. Such loadings increase dramatically over the summer tourist seasons at many of these plants.

Raw sewage overflows from pump stations occur periodically in parts of the District, typically where stormwater has not been separated or not successfully separated (possibly through ingress) and heavy rainfall events producing more stormwater than the reticulation system can cope with.

State

"State of the Environment" and compliance monitoring programmes have indicated that there are large variations in the quality of effluent (sometimes well above guideline or compliance limits) and that this consequently has large effects on the quality of receiving water. Faecal bacteria concentrations at the mouth of the Aorere River downstream of the Collingwood sewage treatment plant and dairy farm effluent discharge receiving waters are regularly above national stock drinking water guidelines.

Localised drains and small waterways in areas such as Little Kaiteriteri and Pohara have at times been highly contaminated with faecal material from the discharge of untreated or poorly treated sewage.

Response

Sewage Treatment System Upgrades: Upgrades are either in process or imminent at Tapawera, Murchison, Motueka, Takaka and Collingwood. The Collingwood sewage treatment plant, which currently consists of an oxidation pond and artificial wetlands, is due to have a UV treatment system added on in mid-2005.

Sewerage Reticulation Projects: Several townships have had reticulated sewerage installed in the last five years including St Arnaud, Richmond (Hill Street), Motueka, Tapu Bay-Kaiteriteri and Takaka/ Pohara.

Stormwater-Sewer Separations: A programme of separation of stormwater and upsizing of sewerage reticulation systems is ongoing.

Monitoring: Tasman District Council contracts MWH Ltd to monitor all sewage discharges it is responsible for. This monitoring occurs at a frequency of six samples per year and quantifies flow and several water quality parameters. TDC compliance officers audit these discharges annually and more often when the facilities are non-compliant.

Septage (septic tank discharges)

Pressure

Potential environmental effects of discharges from septic tanks are similar to that of sewage (see above) but adverse effects are more likely to manifest where septic tanks are concentrated near waterways, soil permeability in the infiltration field is low (e.g. clay soils) or very high (e.g. sand/gravel) and/or they are poorly maintained.

State

Very little information is available on the effects of septage on waterways. There are several examples where national guidelines for contact recreation have not been met due to septage discharges to water. However, most of these investigations are as a result of complaints or from sanitary surveys that follow-up when a bathing area fails to meet guidelines.

Response

Compliance of such discharges is not routinely monitored by Council but is responded to as a result of complaints from the public or when identified through other monitoring acitivities.

However, a survey of groundwater in Golden Bay in areas where septic tanks are common was undertaken in January 2005. Sixteen out of a total of 23 bores sampled had detectable *E. coli*, with a mean of 5.1 *E. coli*/100ml. Five results were in the range 100-270 *E. coli*/100ml. Generally, these concentrations are expected to be further reduced by natural die-off on the passage to waterways and therefore not considered a likely threat to surface water, although serious if consumed from the bore supply.

In some areas where septage is known to be an issue "Warrants of Fitness" for the individual treatment systems could be issued on a regular basis, as happens in Marlborough.

Discharges in excess of 2 m^3/day, or those in defined sensitive receiving environments, require resource consent and are monitored annually. Any discharge, whether permitted or consented, found to be non-complying, is liable to some form of enforcement, and in most cases, the issue of an abatement notice.

6.2.2 *Discharges from Farms and Fertiliser Operations*

Pressure

Untreated or poorly treated farm dairy effluent contains high concentrations of contaminants that are either toxic (such as ammonia), or potentially disease causing. Fertiliser run-off can cause nutrient enrichment and consequent prolific growth of aquatic plants and algae. The visual clarity of the water is often reduced, which affects aesthetic quality and the ability of fish to locate prey. Beds of waterways can become covered with manure solids.

The small to medium sized creeks and streams (first, second and third order) are the most vulnerable to pressures from dairy farm activities.

There are currently 33 dairy farms that discharge treated effluent directly to water in the District. A further six that currently discharge to water are planning to discharge to land, or have applications for discharge to water pending.

High cattle stocking densities have been correlated in some areas with poor water quality. Stocking rates in the District are variable, with a range from 1-6.8 cows per hectare. The following is a breakdown of stock per locality: Rockville: 1.5-3.5 cows/ha, Pakawau 1.5-4.0 cows/ha, Motupipi-Wainui 2-4 cows/ha, Korere 1-2.5 cows/ha and Waimea 2-6.8 cows/ha. However, Nottage (2000) found for streams in the Aorere catchment that there was a poor correlation between these factors.

Fonterra and the Ministry for the Environment have recently published a report on the progress on these issues on a region-by-region basis. The performance of farms in Tasman District compared to the rest of the country was generally below average, particularly for employing nutrient budgets, percentage of farms with unbridged regular crossings and effluent discharges. However, Tasman District was slightly above average for restricting of stock access to waterways.

State

The effects of agricultural development on water quality and stream health has become widely recognised throughout New Zealand over the last two decades (Wilcock, 1986; Quinn et al., 1997; Harding et al., 1999; Quinn, 2000; Parkyn and Wilcock, 2004). The effects of urbanisation on water quality and stream health are also well known (Suren, 2000; Suren and Elliott, 2004). The main threats to water quality and stream health in the Tasman District relate to the recent and continuing intensification of agriculture in the District, and to a lesser extent the expansion of residential development. The effects of intensive horticulture on streams is not well known. The Kikiwa suite of sites (Hunter Ck, Kikiwa and Graham Stm) in the upper Motupiko River Catchment provides a useful comparison of land use effects, as each site is almost completely dominated by either sheep and beef, exotic forestry or native forest, while having very similar geology, source of flow, network position and valley landform. Kikiwa Creek with sheep and beef has significantly higher *E. coli* and nutrient concentrations compared to the other two land uses (median: 300 *E. coli*/100ml compared to a median of 15 and 10 for Graham and Hunter Creeks respectively). Motupipi River and Sherry River at Blue Rock, whose catchment is dominated by dairy farming, also has high *E. coli* concentrations (median: 375 and 400 respectively). The reference site on the Sherry River showed a median of only 35 *E. coli*/100ml). The Kaituna and Onekaka Rivers showed reasonably low median *E. coli* concentration (100 and 177.5 respectively) but the proportion of the catchment in dairy farming was significantly less. The recreational water quality monitoring site on the Takaka River at Paynes Ford showed two significant exceedances of guidelines in early 2005 after a particularly wet period. These results could be due to run-off of farm effluent, as most of the farms up the Takaka valley discharge to land and do not have holding capacity to avoid this during wet periods.

The removal of riparian vegetation and resultant loss of shading from many streams has caused water temperatures to be elevated to the point where many aquatic organisms die. Careful management will be required to ensure that water quality and stream health does not decline as a result of these changes in the District.

Response

Most farmers now use commercial fertiliser applicators to spread phosphorus and lime and almost all these applicators have "Spreadmark" certification that dictates a number of environmental controls. Nitrogen fertilisers such as ammonia-urea are spread by farmers themselves, as the timing of the applications is more critical.

In general, there has been little uptake by farmers for creating wetlands for nutrient or sediment run-off retention.

TDC has encouraged and promoted the formation of Landcare Groups with an interest in environmental quality and worked with them to achieve their environmental goals. One of the most successful Stream Care groups in the District is operating in Murchison. This group has protected creeks near the township with fencing, removing weeds and planting.

The use of the Stream Health Monitoring and Assessment Kit (Biggs et al., 1998) should be encouraged for the monitoring of impacts on water quality, particularly from dairy farming activity.

Discharges of dairy farm effluent to land are audited against the permitted activity rules (Chapter 36.1.3 of the proposed Tasman Resource Management Plan) once every five years. This is programmed to change to biennial monitoring, with a report on findings published at the completion of each two yearly cycle. All consented dairy farm effluent discharges to water are inspected annually and are sampled for Biological Oxygen Demand (the potential for the waste to reduce the dissolved oxygen in the receiving water) and suspended solids. It is recognised that such discharges should be sampled in addition for faecal coliforms and ammonia, as these are the parameters most likely to compromise values in the downstream catchment e.g. bathing beaches, shellfish farming and aquatic ecology. Resource consent conditions should also require additional monitoring (two to three times per year unless there has been a high level of compliance. Future consent will require compliance limits applied to the receiving water.

Stock crossings and the presence of cattle in creeks have been shown to cause a major loading of disease-causing organisms to waterways (Davies-Colley et al., 2004). TDC has recently set up an intensive sampling programme of waterways in farmland to determine the locations and activities that cause major faecal bacteria loads to the coast, affecting shellfish farmers and gatherers. Following on from this study corrective actions have been identified. Advice and promotion of bridging or culverting waterways has been given by Council and Fish and Game on these issues and many farmers have taken this positive action, particularly in the Sherry River catchment. An inventory of major crossings has been undertaken by Council staff. Many feed pads and stand-off pads located close to waterways have been re-sited and associated effluent better managed.

A comprehensive survey of waterways on farms has recently been undertaken in Golden Bay to determine the major sources of faecal contamination to the marine environment.

The Dairying and Clean Streams Accord was signed by Fonterra Co-operative Group, Ministry for the Environment, Ministry of Agriculture and Forestry and Local Government New Zealand in May 2003. This has led to stronger commitments to address these issues. A regional action plan relating to the Accord is close to being ratified.

6.2.3 *Stream Habitat Modification*

Pressure

Removing riparian vegetation, installing in-stream ponds and rock armouring of the stream bed can lead to high water temperatures, particularly in small waterways. Even after stream replanting, streams may take years to achieve satisfactory temperatures due to the time it takes for trees to become large enough to produce shade.

State

Widespread and frequent exceedance of temperature criteria for protecting ecosystem health was observed in the Motueka catchment (see Figure 20) and Reservoir Creek.

Response

In recent years farmers have put considerable effort into stabilising streams, not only to preserve farmland, but also for reasons of stream habitat and controlling stream temperature. However, streams on sheep and beef farms tend not to be fenced or stabilised. The TDC subsidy for fencing and stability works is always fully subscribed.

TDC is looking at revising its Engineering Standards and Policies to include stream redesigns that will maintain more natural water temperatures.

6.2.4 *Damming and Taking Water*

Pressure

Damming water can lead to higher water temperatures if the discharge from the dam is from the surface or low dissolved oxygen if the discharge is from the base of the dam. Taking a large percentage of the flow in a waterway can adversely affect water quality by reducing the amount of available dilution for discharges to water and contributes to excessive water temperatures during warm summer periods.

State

Limited information exists on the effects of large water takes or cumulative effects of multiple takes on water quality. It appears that there are few situations where there are significant discharges to water where such takes occur (excluding the Moutere Ditch). The temperature of water released from the Cobb dam is on average 4^{o}C higher in summer than neighbouring catchments (Young et al 2000).

Response

Limits are placed on how much water can be taken from particular catchments via the proposed Tasman Resource Management Plan. These limits seek to preserve sufficient flows to avoid adverse environmental effects. Most consented water takes are required to fit water meters and record the amount of water used. This meter data is monitored by Council through the irrigation season and audited on a regular basis, with sporadic site inspections occurring in addition. Rationing of water takes is instigated from time to time during periods of drought. The taking of water for stock drinking water and water takes up to 5m^3/day are permitted, although subject to conditions that seek to avoid adverse environmental impacts resulting from low flows.

6.2.5 Discharges of Sediment from Earthworks and Stockpiling of Material

Pressure

Discharge of sediment with stormwater run-off from earthworks such as subdivision development, roading and pasture redevelopment can cause:

(a) reduction in water quality, as indicated by reduced clarity;
(b) smothering of aquatic organisms by sedimentation of the stream bed.

Such earthworks activity is particularly apparent in the Moutere Hills, St Arnaud and in Reservoir Creek catchment. Major quarries include a dolomite quarry in Aorere Valley, near Collingwood, several hard rock quarries up the Wairoa and Lee river valleys. Alluvial gold mining operations, such as in the Matakitaki River catchment, have considerable potential to discharge fine sediment.

Although sediment loading to waterways is often naturally high during and after rainfall, the settling velocity is low due to high horizontal river velocity. Comparatively low sediment deposition occurs compared with high sediment discharges from various activities at times of low flow. As has been described earlier, small streams are more vulnerable but small spring-fed streams are even more vulnerable, due to infrequent high-flow events that would flush out the sediment.

State

Water clarity of the Takaka River downstream of the Cobb powerhouse was often poor in 1999 and little information has been collected since then. The level of fine sediment in the bed of the Onekaka River downstream of the dam has been high on occasion. “State of the Environment” monitoring results from the Matakitaki River show considerable amount of fine, pale grey-coloured sediment within the bed matrix and banks. Macroinvertebrate results are variable, with spring 2001 and spring 2003 showing a marked reduction in species richness and total number of mayflies, stoneflies and caddis flies at the Murchison site compared to the Horse Terrace site upstream of most of the mining activity. No significant difference was found between all three sites on the Matakitaki River for the 2002 sample set. It is not known when the main mining activity occurred in this catchment and hence whether this poor condition can be correlated to the mining activity.

A small partly spring-fed creek in Murchison has recently been found to contain a heavy fine sediment load, most likely from a relatively small yard development that did not protect sediment run-off during a storm event. This situation is likely to affect trout spawning in this creek. A heavy sediment load is also found in the Motupipi River, which is also spring-fed.

A report on the effects of gravel extraction from the Wairoa River showed significant adverse effects on macroinvertebrate species richness but only minor effects on total macroinvertebrate abundance (Kelly et al., 2005). It could be that substrate size is the major factor governing invertebrate species richness, as this was the main physical habitat feature that changed downstream of gravel harvesting areas.

Response

Most earthworks work parallel to the contours, which reduces the sediment run-off considerably compared to working up and down slope.

The main river channels upstream and downstream of river-based gravel extraction operations, such as for river maintenance purposes, are generally inspected monthly, after water has been bank to bank as a result of storm event, or as necessary. A more thorough site inspection is carried out as part of every resource consent application and upon completion of works approved by the consent. This includes a site visit with the consent holder prior to the exercising of consent. Council's Asset Engineer (Rivers) and Resource Scientist (Rivers) also comment on any gravel extraction consents received.

Inspections of quarries and mining is generally carried out annually, however, some large quarries have not been monitored for some time now.

6.2.6 Forestry

Pressure

Forest harvest operations have the potential to detrimentally affect the quality of adjacent water bodies with discharges of fine sediment and woody debris. If a riparian buffer zone is not left (i.e. trees are harvested right up to stream bank), harvest operations have been shown to change the amounts and characteristics of woody debris in streams and increase channel bank disturbance, i.e. erosion. Additional woody debris enters the stream channel from thinning operations and windthrow. Large amounts of woody debris, particularly finer particles such as pine needles, in water bodies can impact their water quality. However, removal of most or all wood from a stream channel can raise water temperatures to levels that can be stressful to some aquatic animals (Baillie and Cummins, 1998) and reduce the available habitat.

A relatively large proportion of the Tasman District is covered by exotic forest (particularly in the Wairoa, Lee and Motueka catchments). Other forestry activities can impact on water

quality and stream health (Harding et al., 2000; Fahey et al., 2004). Land preparation and forest establishment produced about 7.5% of the background sediment production with roading making up about 0.75% of background production on an annual basis (Fahey et al 2004). Nevertheless, large inputs of sediment discharged to waterways after rainfall events may have longer lasting effects in the coastal and marine environment.
Pinus radiata forest tends to produce lower catchment yield (rainfall run-off to waterways) as a result of rainfall interception and evapotransporation than other forest or pasture.

State

Data reviewed here from sites draining catchments dominated by mature exotic forest generally had water quality and stream health that was equivalent to that in native forest.

Graynoth (1992) suggested that reduced stream flows on the Moutere gravels caused by mature *Pinus radiata* may have more serious impact than short-term effects from sediment discharges.

In the larger catchments on the West Bank of the Motueka River where production forestry only covers about 20% of the catchment, there are only small effects due to harvesting operations (Hewitt, 2002). However, in the smaller Kaiteri Forest where the catchments are much smaller, and percentage forest cover much greater, harvesting effects are much greater. In the West Bank Forest, where catchment areas range between 8 and 26 km^2, sediment yields vary from 20 $t/km^2/year$ pre harvest, to 150 $t/km^2/year$ 'during' and post-harvest. Unlike in the Kaiteri catchments, there was no measurable difference in sediment-concentration/flow rate relationships from 'during' to 'post harvest' in the West Bank catchments. In the Kaiteri Forest, sediment yields ranged from 40 $t/km^2/year$ pre harvest, to 378 $t/km^2/year$ at the peak of harvesting. Bedload was recorded in the Kaiteri catchment at an average rate of 27% of total sediment load from that catchment.

Response

In harvesting operations, the forestry industry makes extensive use of aerial hauler systems that lead to considerably less sediment run-off compared to a decade or more ago when skidders were used to drag logs over the land surface and through streams. Maintaining riparian buffer strips was introduced as general practice by the major forestry companies in the late 1990s.

The larger forestry companies in this District follow comprehensive environmental management systems that have been developed under ISO 14000. These systems require that if any issues arise from their operation, including any complaints from the public, irrespective of the requirements of the resource consent, an incident investigation be undertaken and communication with TDC and sometimes other stakeholders. General inspections of forest harvesting or roading operations by Council is undertaken as required and auditing of forestry companies' operations are carried out by Council and other independent auditors. A TDC officer is represented on the Weyerhaeuser Environmental Improvement Committee, which assists greatly in communicating objectives and ideas for environmental improvement between the organisations.

TDC planning rules now restrict the area of a title that can be planted in new forest in Moutere gravel terrain to no more than 20% to ensure higher water yields are maintained.

6.2.7 Industries Storing or Using Hazardous Chemicals

Pressure

Discharges of contaminants to surface water (often via groundwater) from landfills, timber treatment plants, petroleum installations and trade waste from many types of industries have the potential to cause considerable environmental damage through toxicity of the material and bioaccumulation. Sixteen closed and two open Council-run landfills exist in the District, with the Eve's Valley landfill being by far the largest. The toxin 1080 (sodium monofluoroacetate), which is used widely throughout the District to limit bovine tuberculosis (Tb) spread and for nature conservation purposes, and pesticides from horticultural operations have the potential to get into waterways and cause adverse effects, particularly from discharges resulting from poor application practices and the rinsing of used pesticide containers. Organo-chlorine pesticides, such as dieldrin, aldrin, DDT, dioxins and furans, are particularly long-lived in the environment as well as being very toxic in high enough concentrations. Lead arsenic was used as an insecticide in sheep dips and horticultural crops, and these harmful residues remain in the soil and then could be mobilised through erosion and discharged into waterways. Discharge of household chemicals to waterways has the potential for serious adverse effects.

These include the large scale industries of Dynea and Nelson Pine Industries to car wreckers, transport yards and truck washes, vehicle workshops, concrete and cement plants and spray-painters. Most of the smaller industrial premises in lower Richmond (including the transfer station) were found to discharge untreated stormwater into waterways. Poor on-site management of potential spills and inappropriate storage of hazardous substances is also likely to contribute to the risk of contaminants entering these water bodies.

State

A survey of discharge to stormwater from the Richmond industrial area was carried out in 1998 and 2004 (Easton, 2005). Moderate to high concentrations of heavy metals and poly aromatic hydrocarbon contaminants were found in waterways receiving run-off from industrial land in Richmond. By comparison, the study showed low concentrations in urban and rural catchments near Richmond.

Limited monitoring of waters receiving landfill leachate has indicated adverse effects only in small waterways. Sediments of waterways near the Richmond landfill were found to have high concentrations of heavy metals.

It is not known whether pesticides are found in waterways and if so, what effect they may be having. Only two monitoring sites in the current "State of the Environment" programme are on waterways where the dominant land use of the catchment is horticulture (Little Sydney and Riwaka) and no pesticides are sampled. Ministry for the Environment (1999) conducted a survey of shellfish and sediment in estuarine sites throughout New Zealand in 1998, including two sites on the Moutere Inlet, and found very low organo-chlorine concentrations.

Sampling by the Animal Health Board and Department of Conservation carried out before and after a 1080 operation shows no significant adverse effects on water quality or aquatic ecology (Broome et al, 2005 and from numerous compliance monitoring reports supplied to TDC).

In 2003 a pesticide was dumped to stormwater in the urban area of Richmond, which then flowed into Jimmy Lee Creek and caused considerable eel deaths.

Response

Landfills: All of the 16 closed Council-run landfills in the District are inspected annually and samples of leachate are collected if leachate intercepts the surface. Groundwater sampling has only been carried out at three of these sites. At one of these sites contaminant concentrations were found to be elevated and remedial measures (including capping and armouring) were undertaken but no further sampling has been carried out to confirm the action was effective. Management Plans for all closed landfills should be produced to ensure any adverse effects of future management are taken care of. Monitoring of the new Stage 2 of Eve's Valley landfill has begun after a two year delay.

Timber Treatment Sites: Of the five timber treatment sites in the District, only two are monitored (on an annual basis). The largest site, near Motupiko beside the Motueka River, has recently upgraded the site's stormwater management. In response to the recent (March 2005) flood event, work has been done on the stopbanks to protect this site and a further site upgrade to ensure the timber treatment chemicals are contained. Upgrades are being planned for the plant located near the Little Sydney Stream near Riwaka. Another large operation in Richmond was prosecuted by Council in 2004 for discharges of tributyl tin to Vercoes Drain, which flows into the Waimea Estuary.

Petroleum Installations: Groundwater contamination is known to occur from historic service stations in two locations and these are being monitored. The 29 operating service stations and large fuel facilities in the District have been required to upgrade to meet the Council's hazardous facility rules. Currently, there are only a few sites yet to comply with these rules.

Trade Waste: No Trade Waste Bylaw exists in Tasman. However, an Australia-New Zealand Standard is being developed that may be used in Tasman in the future. Potential contaminants from trade waste should be monitored regularly, such as the leachate being reticulated to Bell Island wastewater treatment plant from Eve's Valley landfill.

1080: Many methods to reduce potential adverse effects from 1080 applications are employed, such as reducing the concentration of 1080 in pellets used in applications and requiring global positioning systems to be fitted to all aircraft to control the application of 1080 and reduce the amount deposited in waterways. Water quality sampling occurs after most aerial application operations.

It has been identified that management of many industrial discharges needs to be improved. Few industries have resource consent and few are monitored adequately, and then mostly in response to complaints. Hazardous facilities are monitored annually as a minimum. Those that are required to are presently going through resource consent process. A Motueka industry survey has been undertaken and remedial action taken where issues were identified. A new survey for Richmond's industrial sites is planned within the next year.

Dynea and Nelson Pine Industries have facilities for collecting and treating stormwater and process water from their sites. The limited amount of monitoring to date shows contamination of estuarine sediments is not significant around these two sites.

Council's Environmental Education Officer has led an effective campaign to educate the community as to the negative effects of tipping chemicals and disposing of car-wash effluent to stormwater. Yellow fish are painted on the majority of stormwater grates in major urban areas in the District to remind people of where the drain ends up.

6.2.8 Orcharding

Pressure

Apple dump wastewater contains mostly sediment, but there can be low concentrations of pesticides washed off the apple skins and traces of chlorine (15-50 ppm), which is sometimes added to the dump water to inhibit stem rot. Combined with a rate of discharge in the range of 5-20 m^3/week, there is potential to cause environmental problems if not done properly. It is estimated that over 7,000 m^3 of apple dump water is discharged to land throughout Tasman District over the 12–16 weeks duration of the packing season (Milson, April 2004). Between 2001 and 2004 the number of packing houses decreased from 55 to 36. However, the total area of orcharding land had not declined significantly.

State

It appears that no waterways have been sampled for chemical residue where orchards are the dominant land use in the catchment.

Response

Based on a study undertaken by the TDC in 1993, it was recommended that the apple dump wastewater should be disposed to land (where sunlight and natural soil micro-organisms would be expected to break down the contaminants) rather than into waterway where the toxicity of contaminants could cause problems to aquatic life (Milson, April,2004). Rules controlling apple dump wastewater disposal were put in place shortly after.

Pesticides used currently include Diphenylamine, Dithiocarbamates, Dodine, and Chlorpyrifos. Azinphos–methyl, Carbaryl, Gusathion Diazinon, and Atrazine are either banned, being phased out or no longer in use due to their high toxicity in aquatic ecosystems. Given this development, free chlorine is now the contaminant of most concern. A number of orchards visited were adopting biological methods for pest control, using pheromone strips at key times of the apple growth cycle. A 14 day minimum withholding period between the final spray application and picking the apples seems standard, and this should help reduce the level of toxic chemicals in the spent apple dump water. Spray diaries are closely monitored by Pipfruit New Zealand (PNZ) and the Integrated Fruit Production (IFP) system. Apples are routinely tested for chemical residues as part of these, ENZA, AgriSure and other export programmes.

In addition to annual compliance audits, detailed compliance assessments were undertaken by TDC in 2001 and 2004. The latter follow-up also included a compliance assessment of discharges of smaller volumes of effluent from the packing house drench plants which require disposal. One of the drenches in common use is toxic and these residues must also be disposed to land, well away from any waterways. However, this drench is likely to be phased out in the next few years. Those orchards who were not complying (<10% of all visited) were followed up appropriately.

Through TDC's interaction with orchard owners or managers there was a high level of awareness and increased compliance of the TRMP rules relating to the disposal of spent water from the apple dumps. Also, more attention appears to be being given to apple spray programmes than in the past to improve the efficacy of the sprays and to reduce their usage. The TRMP rules and industry's own best practice guidelines appear to be effective at controlling environmental effects.

In general, the standard of spray sheds was very high, with the requirements of location (not prone to flooding), spill containment (bunding), security, Hazchem signage, ventilation and personal protective equipment (ppe) being met. Fuel storage was not to such a high standard, with many tanks being unbunded, the drain pipes on many that are bunded being in an open position (making the bund ineffective), and many with diesel spills on the ground. A number of bunds were full of water (also making the bund ineffective) and/or rubbish and required cleaning out.

The Hazardous Substances and New Organisms (HSNO) regulations which came into force on 1 April 2004 (hazardous substances) and 1 July 2004 (pesticides) create new requirements for the storage and handling of these materials, in addition to Council requirements, and all landowners will need to ensure they comply with the new regulations.

6.2.9 Winery Waste Disposal

Pressure

The three main discharges associated with winery operations are:

(a) wash water from rinsing bottles and barrels and washing floors and tanks;
(b) domestic wastewater from staff or café ablution facilities;
(c) leachate from composting marc and other organic solids.

The sugar content of winery waste causes the washwater and leachate to have a high biochemical oxygen demand, which has the potential to reduce dissolved oxygen concentrations in waterways to a level that could kill aquatic organisms. The level of nutrients, suspended solids and the pH of the discharges of winery wastes may also have adverse effects on the receiving environment. Winery washwater is either drained directly to land, or run into ponds for the irrigation water supply. In one case the water is stored and removed by a liquid waste contractor. Most solid wastes are composted and discharged to land or fed to stock.

The area in vineyards increased in the Tasman District from 256 hectares in 2001 to 454 hectares in 2004 but the number of processing facilities reduced by nearly half (Milson, May 2004).

State

It appears that no waterways have been sampled where vineyards are the dominant land use in the catchment.

Response

Compliance assessments were carried out in 2001 and 2004, both showing a high standard of compliance and there was good awareness within the winemaking community of their obligations for waste management. Four of the composting operations require some improvements to ensure that leachate is more adequately controlled. The wine industry has developed their own standards (SWNZ – Sustainable Winegrowing NZ) to help minimise the environmental impact of grape growing and processing.

6.2.10 Other Fruit Growing

Pressure

Berry fruit waste has high BOD and colour.

State

No systematic monitoring of berry fruit farms has been undertaken.

Response

Occasional inspections of some berry fruit farms.

6.2.11 Market Gardening

Pressure

Wastewater, particularly from hydroponic greenhouse discharges and leachate from composting operations contains high concentrations of nutrients. Intensive water and fertiliser use occurs, enabling many crop rotations to occur each year.

State

It appears that no waterways have been sampled where market gardening is the dominant land use in the catchment. Many market garden operations regularly use chicken manure as a fertiliser source.

Response

No monitoring is carried out for hydroponic greenhouse discharges, although it is anticipated to occur as part of a nitrate management review in the Waimea plains.

6.2.12 Fish Farms

An independent consultant monitors the two farms monthly or bi-monthly, with TDC auditing annually. Occasional minor non-compliance has been recorded with respect to water clarity.

6.2.13 *Miscellaneous Discharges*

Pressure

Discharges of sawdust, lawn-clippings and other organic waste can smother the beds of waterways and lower dissolved oxygen.

State

Lawn clippings disposed of beside a tributary of Reservoir Creek were found to be the cause of low dissolved oxygen and poor macroinvertebrate condition in this tributary.

Response

Education and enforcement measures to be implemented as appropriate with respect to discharges to waterways.

6.3 Other Responses

Integrated Catchment Management

In the Motueka catchment considerable research is being put into resource management issues over a range of scientific disciplines. The Motueka Integrated Catchment Management (ICM) seeks to create integration amongst scientific disciplines, between communities, scientists and environmental managers within the catchment boundary. A report summarising the current state of knowledge in the Motueka catchment was produced in 2003 (Basher, 2003; this can be downloaded from the following website: http://icm.landcareresearch.co.nz/Library/project_documents/ICM%20Report.pdf). There have been a number of water quality investigations, many of which have been discussed in this report. In addition, the following projects have been completed or ongoing:

(a) riparian vegetation assessment for the Sherry River;

(b) assessments of various native plants at stabilising stream banks, culminating with workshops on the topic;

(c) investigations into the riverine effects on coastal habitats in Tasman Bay, including nutrients and sediment;

(d) developing an environment for social and cultural learning, collaborative research, and partnerships to improve knowledge uptake.

Water Conservation Orders

Water Conservation Orders have been designated for large parts of the Buller and Motueka Catchments. These designations are set up to protect waters of outstanding importance for amenity or intrinsic values. Fish and Game applied for both Water Conservation Orders to protect the trout fishery, wild and scenic character.

7 RECOMMENDATIONS

7.1 Changes to the Monitoring Programme

While recognising the value of a long-term data set that is based on consistent high quality data from the same sites using the same parameters and similar sampling intervals, there is little value in maintaining the status quo if there are good reasons to make changes to a monitoring programme.

7.1.1 ***Add more sites on small streams*** to the programme. Small (first and second order) streams are highly under-represented compared to the percentage of these streams in the District. Small streams are the most vulnerable to pollution. Any new sites chosen should cover both "reference" sites draining areas that are largely undisturbed and "impact" sites that are currently facing pressure, or are likely to in the near future. Several sites on small streams were added in late 2004.

7.1.2 ***Rationalisation to enable adding sites as above***

(a) **Remove some sites on larger waterways** in order to add sites on small streams. Sites that are candidates for being dropped or moved are: *Aorere at Devil's Boots, Wai-iti at Pigeon Valley, Wairoa at Irvines*. Sites dropped in the last year: *Buller at Lake, Glenroy at Bridge, Matakitaki River at Nardoo, Matakitaki at Horse Terrace, Motueka d/s Graham*. Reasons for dropping these sites are explained in a report on surface water quality for the upper Buller catchment (James, 2004).

(b) **Cease collecting data from NRWQN sites** other than faecal indicator bacteria.

(c) **Cease collecting samples for *Total nitrogen* and *total phosphorus*** analysis except at downstream sites of the large river catchments throughout the District. **Cease sampling for *Total, Fixed and Volatile suspended solids*** unless for targeted impact investigations to identify the likely causes of poor water clarity or high turbidity.

7.1.3 ***Collect macroinvertebrate samples biannually*** (once in spring and once in autumn) **for the next two years** and then move to autumn thereafter. This is due to unpredictable weather and flow conditions in spring often upsetting sampling plans and worst-case stream health will generally occur in late summer as a result of low flows, algae accumulation and warm water temperatures. Sampling in both spring and late summer should be undertaken for at least two years to identify the likely seasonal changes in macroinvertebrate community composition at the sites.

7.1.4 ***Determine the behaviour of contaminant load semi-continuously over a few flood events*** upstream of sensitive receiving environments e.g. faecal bacteria delivered from the Aorere River to Golden Bay. In this case, the load delivered during large floods will probably be much greater than that delivered over a much longer time period at low flow. Therefore, automated flow-weighted samplers that would sample water throughout floods would be required to calculate an accurate load to the Bay. This kind of sampling is expensive and logistically difficult as staff have to be on standby ready for a flood event. This work is being undertaken in the Motueka River catchment as part of ICM research and has been undertaken in the Aorere River at Devil's Boots.

7.1.5 ***Increase sampling interval***. To be able to detect trends in water quality in the District in less than 10 years from now, more frequent sampling is required. This increased frequency could be carried out at a selection of sites to limit increased costs. This is a medium priority but will add significantly to the cost.

7.1.6 ***Undertake semi-continuous sampling for dissolved oxygen, pH and temperature at all sites*** on a rotational basis. These parameters can vary considerably on a 24 hour cycle, meaning that discrete samples should be collected at the same time of day at all sites to be able to compare results with any real meaning. Obviously, this is not possible unless deploying field meters that log data. TDC has two of these and can hire or loan one or two more, enabling efficient and cost-effective coverage of sites. This is a high priority with little extra cost.

7.1.7 ***Install turbidity and conductivity probes for continuous sampling*** at key hydrometric stations. Once a correlation is established between these parameters and contaminants such as faecal bacteria and nutrients, the total loading can be established at a range of flows at relatively low cost. These could be established at downstream sites of the large river catchments throughout the District (the last three sites listed above). Low-medium priority.

7.1.8 ***Increase targeted impact investigations*** to be able to determine the effects of specific activities within a land use. Part of the annual budget could be dedicated to this type of monitoring to be able to respond to new land use pressures occurring in different areas. It is also a case of moving through the list of priorities ranked on environmental risk. Priorities for such investigations include:

(a) determining what, and where are the activities within the dairy farming land use in Tasman District that generate the highest faecal bacteria loads. Such investigations have begun in coastal western Golden Bay;

(b) what are the causes of the high nutrient load to the Motupipi River? This could potentially involve groundwater monitoring, given that this waterway is fed largely by groundwater;

(c) determining the effects of sewage or septage on waterways from new cluster housing subdivisions such as those proposed in the Moutere. This has implications for planning rules for the Rural 3 Zone.

7.2 Information Management

7.2.1 ***An inventory of environmental information should be set up*** using a Web-based, spatially referenced system. This could be integrated with nationally-based systems such as Terrestrial and Freshwater Biodiversity Information System (TFBIS).

7.2.2 ***Implement a data management system***. A comprehensive Council-wide needs analysis has been undertaken and a software package has been chosen after a thorough decision process.

7.2.3 ***Development of Web-based reporting systems*** to ensure that up-to date information is delivered to the public, thereby adding a lot more value to this monitoring programme. This should not replace the production of more detailed reports, such as this, or oral delivery of this information, such as at planned seminars and road shows.

7.2.4 ***Develop the NCS consents database*** so that consents can be sorted by land use or activity type within a catchment or area and output plotted on a map. This is necessary for trying to determine cause and effect. However, this sorting is a very tedious manual process at present.

7.3 Internal Communications Strategy

As environmental issues emerge through complaints and monitoring, systems for efficient and effective feedback between consents, planning, resource science, parks and reserves and engineering should be developed.

7.4 Resource Consent Processing

Consent decisions should be better peer reviewed and discharges to water should include receiving water monitoring where appropriate. Ensuring resource consents for discharges to water, including stormwater, are processed in a timely fashion for higher risk industrial activities. A greater emphasis should be placed on receiving water sampling to determine loadings from individual activities.

7.5 Compliance Monitoring

7.5.1 Resources for **compliance monitoring activity** should be increased, particularly in the short-term with respect to the following:

(a) dairy farming discharges to land and water, stock crossings, feed pads and stand-off pads, stock access to waterways and management of wetlands. The frequency of monitoring of such activities should be increased to biennial at least and biannual for discharges of dairy farm effluent to water. Farmers should be assisted in defining priorities for improving environmental performance on their farm based on environmental risk. This should go hand in hand with education, particularly around the Clean Streams Accord, which is about to be signed by Fonterra and TDC. A road show on this topic is planned for mid-June.

(b) discharges, including stormwater from higher risk industrial activities such as landfills, timber treatment facilities and workshops.

7.5.2 More effective **recording of complaints** to be able to determine a more representative summary of public opinion. High priority and low cost.

7.6 Education

Provide more advice and assistance to those resource users who need to improve their performance.

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APPENDIX 1

Details and REC Classifications of the Core Monitoring Sites

Appendix 1: Details and REC Classifications of the Core Monitoring Sites

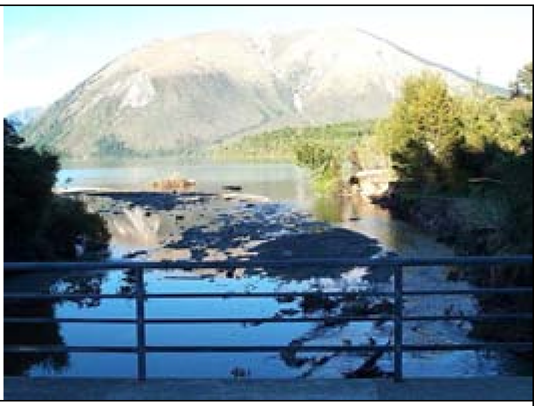
REC classification codes are defined in Table 2.

Site	Site Type	Northing	Easting	Order	Climate	Source of Flow	Geology	Land Cover	Valley Landform
Aorere Rv @ Devil's Boots	SoE	6051093	2478458	5	Cx	h	hs	if	lg
Aorere Rv @ Le Comps	SoE	6059618	2479877	6	Cx	l	hs	if	lg
Black Vly Stm @ d/s Borlase Ck	SoE	5933955	2497730	3	Cw	h	al	p	lg
Black Valley Stm @ Lk	SoE	5933399	2497210	3	Cw	h	al	p	lg
Buller Rv @ Lk Rotoiti	SoE	5933881	2495090	4	Cw	lk	hs	if	lg
Buller Rv @ Longford	NRWQN	5937850	2459080	6	Cw	h	hs	if	lg
Glenroy Rv @ Bridge	SoE	5911398	2454946	5	Cx	h	hs	if	lg
Graham Stm @ Kikiwa	SoE	5950325	2496435	2	Cw	h	ss	ef	mg
Hunters Gully Ck	SoE	5947855	2498785	3	Cw	h	ss	if	mg
Kaituna Rv @ Solleys Rd	SoE	6054596	2477371	5	Cx	l	ss	if	lg
Kikiwa Stm	SoE	5950180	2498150	2	Cw	h	ss	p	mg
Lee Rv @ Meads Br	SoE	5977671	2523275	4	Cw	h	hs	if	lg
Little Sydney Ck @ Factory Rd	SoE	6014545	2508685	3	Cw	l	pl	p	lg
Mangles Rv @ Gorge	SoE	5932021	2462681	5	Cw	h	ss	if	lg
Matakitaki Rv @ Horse Terrace	SoE	5910468	2457382	5	Cx	m	hs	if	lg
Matakitaki Rv @ Murchison	SoE	5933927	2453462	6	Cx	h	hs	if	lg
Matakitaki Rv @ Nardoo	SoE	5910001	2470144	5	Cx	m	hs	if	lg
Motueka Rv @ d/s Graham	SoE	5999225	2496675	6	Cw	h	ss	if	lg
Motueka Rv @ Gorge	NRWQN	5952765	2502705	4	Cw	m	hs	if	lg
Motueka Rv @ u/s Wangapeka	SoE	5985805	2492810	6	Cw	h	ss	ef	mg
Motueka Rv @ Woodman's Bend	SoE	6009190	2506420	6	Cw	h	ss	if	lg
Motueka Rv @ Woodstock	NRWQN	5994315	2495060	6	Cw	h	ss	if	lg
Motupiko Rv @ Christies/	SoE	5954230	2493920	4	Cw	h	ss	p	lg
Motupipi Rv @ Reilly's	SoE	6038938	2495798	2	Ww	l	al	p	lg
Onekaka Rv @ Ironstone	SoE	6047711	2484339	2	Cx	h	hs	if	hg
Onekaka @ Shambala	SoE	6049740	2485129	4	Cx	l	hs	p	lg
Reservoir Ck @ u/s Marlborough Cres	SoE	5984232	2526938	1	Cw	l	ss	p	hg
Reservoir Ck @ d/s Salisbury Rd	SoE	5985819	2526806	2	Wd	l	ss	p	lg
Riwaka Rv @ Hickmott's	SoE	6015495	2509010	4	Cw	h	hs	if	lg
Riwaka Rv @ Nth Branch Source	SoE	6019189	2501658	3	Cw	h	hs	s	hg
Roding Rv @ Twin Bridges	SoE	5980048	2523385	5	Cw	h	hs	if	mg
Sherry Rv @ Blue Rock	SoE	5980625	2487900	4	Cw	l	ss	p	lg

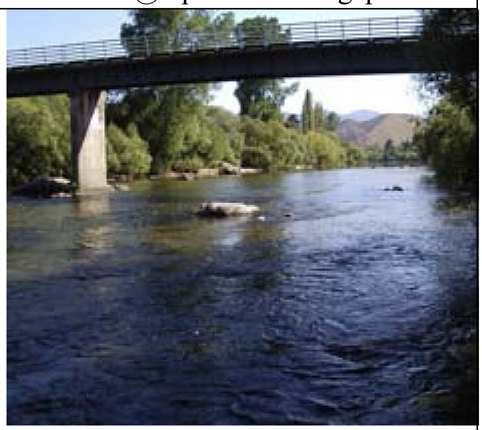
Site	**Site Type**	**Northing**	**Easting**	**Order**	**Climate**	**Source of Flow**	**Geology**	**Land Cover**	**Valley Landform**
Sherry Rv @ Cave	SoE	5968790	2484985	4	Cw	h	ss	ef	lg
Stanley Brook @ Barker's	SoE	5987890	2494925	5	Cw	l	ss	ef	lg
Takaka Rv @ Harwood's	SoE	6019615	2492911	5	Cx	m	vb	if	lg
Takaka Rv @ Kotinga	SoE	6037804	2493907	5	Cx	h	hs	if	lg
Tiraumea Rv @ Track	SoE	5928331	2467872	5	Cw	h	pl	if	lg
Wai-iti Rv @ above Hiwipango	SoE	5963561	2505680	4	Cw	h	hs	if	hg
Wai-iti Rv @ Livingston Rd	SoE	5982866	2518682	5	Cw	l	ss	p	lg
Wai-iti Rv @ Pigeon Valley	SoE	5978026	2513350	5	Cw	l	ss	p	lg
Waimea Rv @ Appleby	SoE	5988556	2520873	6	Cw	h	ss	if	lg
Waingaro Rv @ Hanging Rock	SoE	6029785	2489037	4	Cx	m	vb	if	lg
Wairoa Rv @ Pig Valley	SoE	5970642	2516557	5	Cw	h	hs	if	lg
Wairoa Rv @ Irvine's	SoE	5978179	2520958	6	Cw	h	hs	if	lg
Waiwhero Ck @ Cemetery	SoE	6002085	2504155	3	Ww	l	ss	p	lg
Wangapeka Rv @ u/s Dart R	SoE	5976475	2480520	5	Cx	h	hs	if	mg
Wangapeka Rv @ Walter's Pk	SoE	5985160	2490280	5	Cw	h	hs	if	lg
Watercress Ck @ u/s factory	SoE	6039040	2494310	1	Ww	l	ss	u	lg
Winters Ck @ above culvert	SoE	6041674	2501039	2	Cw	l	ss	p	hg

APPENDIX 2

Photos of Core Monitoring Sites

Buller Sites	
	
Black Valley Stm @ Lake	Mangles River @ Gorge
	
Matakitaki Rv @ Murchison	Mangles Rv @ upstream Tutaki River
	
Matakitaki Rv @ Horse Terrace	Matakitaki Rv @ Nardoo

Waimea Sites	
	
Lee Rv @ Meads Bridge	Roding Rv @ Twin Bridges
	
Wairoa Rv @ Pig Valley	Waimea Rv @ Appleby
	
Wai-iti Rv @ Hiwipango	Wai-iti Rv @ Pidgeon Valley
	
Reservoir Ck @ Salisbury Rd	Reservoir Ck @ Marlborough Cr

Motueka Sites	
	
Graham Stm @ Kikiwa	Kikiwa Stm @ Kikiwa
	
Hunter Stm @ Kikiwa	Motupiko Rv @ Christies
	
Motueka Rv @ Gorge	Motueka Rv @ upstream Wangapeka Rv
	
Motueka Rv @ Woodmans Bend	Motueka Rv @ Woodstock

Motueka Sites (continued)	
	
Wangapeka Rv @ upstream Dart Rv	Wangapeka Rv @ Walter Bluff
	
Sherry Rv @ Cave	Sherry Rv @ Blue Rock
	
Stanley Brook @ Barkers	Little Sydney @ Factory Rd
	
Waiwhero Ck @ Cemetery	Riwaka Rv @ Hickmotts

Golden Bay Sites	
	
Aorere Rv @ Devils Boots	Aorere Rv @ Le Comps
	
Kaituna Rv @ Sollys	Onekaka Rv @ Shambala
	
Motupipi Rv @ Reillys Crossing	Watercress Ck @ upstream factory
	
Waingaro Rv @ Hanging Rock	Takaka Rv @ Kotinga

APPENDIX 3

Environmental Performance Indicators Used in the Surface Water Quality Monitoring Programme

Appendix 3: Environmental Performance Indicators Used in the Surface Water Quality Monitoring Programme

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
Dissolved oxygen	% saturation and g/m^3	Discharge of most organic contaminants to water	Dissolved oxygen (DO) is fundamental to the survival of aquatic life. DO concentrations of less than 5.0 g/m^3 adversely affect trout and less than 2-3 g/m^3 may result in fish deaths. The measurement of DO is particularly important in slow flowing streams with excessive algal/macrophyte growth and little riparian shading where DO may reach low levels. Minimum DO levels usually occur early in the morning (due to respiration of algae and higher plants) and in summer. Therefore, consistency of sampling time, in the diurnal cycle, is often important.	Most natural waters 7-12 (90-100% saturation)
Ammonia * (NH_3-N) or Ammonium-N (NH_4^+-N)	g/m^3	• Dairy shed effluent sewage • Some industrial discharges	Total Ammonia (NH_3+ NH_4) is rarely found in natural waters except in wetlands and geothermal springs. Its presence is therefore an excellent indicator. Total ammonia is an indicator of recent pollution from excrement of animals, and some industries. Ammonia enters surface water and groundwater from decomposition of nitrogenous organic matter. Ammonia (NH_3) is very toxic to aquatic life, with fish (especially trout) being particularly sensitive. Less than 0.1 ppm (0.1 mg/l) has been shown to affect fish species. The toxicity of ammonia is dependent on the concentration of the undissociated form (NH_3), which is controlled by the pH and temperature of the solution (ANZECC, 1992). Ammonia is also a source of nitrogen that, as a nutrient, can cause eutrophication in waterways. Ammonia breaks down to form nitrate, and in so doing consumes large amounts of oxygen.	Raw sewage 30-50 Oxidation pond effluent 20-30 Treated abattoir effluent 50-150 Geothermal springs up to 10.0 Natural freshwater <0.03

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
Temperature	Degrees Celsius	• Any land disturbance that adds sediment to the water body • Removing riparian vegetation	Water temperature has a substantial effect on the functioning of aquatic ecosystems and the physiology of the biota. Physiological processes have thermal optima, and alterations to ambient temperatures may affect the species exposed in a variety of ways. Growth and metabolism, timing and success of reproduction, mobility and migration patterns and production may all be altered by changes in ambient temperature regimes. Effects may be direct through changes to the metabolism, or indirect through the influence on the solubility of oxygen in water. Toxicity of ammonia-N increases with increasing temperature (ANZECC, 1992). Very little expense is required to obtain discrete temperature measurements and real-time (in-situ, field) information is gained. Temperature also influences the amount of dissolved oxygen in water and how much oxygen plants and animals consume. Higher water temperatures mean less oxygen dissolved but more consumed. Extremely high temperatures normally occur in unshaded, shallow, slow moving water during peak summer. Temperatures over 21.5°C have been demonstrated to cause significant adverse effects to native invertebrates and fish.	Takaka Rv Aorere Rv Motueka Rv Waimea Rv
Visual Water Clarity (by Black Disc)	Mm	• Any land disturbance that adds sediment to the water body	Clarity is important because it affects the recreational and aesthetic quality of water. Clarity also affects light penetration into a water body and therefore the whole aquatic ecosystem.	Mean 1200mm

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
		• Any wastewater discharge	Very little expense is required to obtain this type of clarity measurement and real-time (in-situ, field) information is gained. Can be used in combination with suspended solids and turbidity, as all these indicators are not always correlated. This indicator has the advantage over the turbidity that it is cheap and field measurable. Research has shown that people can detect small changes in clarity. Protection of visual clarity will often protect other optical values and avoid regulatory and monitoring complexity. It is important to note: (a) high natural variability in optical characteristics of New Zealand waters (more than one order of magnitude); (b) very clear water can be polluted with contaminants such as faecal bacteria, parasites, heavy metals, ammonia and nutrients.	Naturally clear water (such as for spring-fed streams originating in alluvial material 4000-8000 Naturally turbid water (such as that flowing through soft sedimentary rock. Rivers during flood events 200-300mm Sewage oxidation ponds and dairy shed effluent 200 (range 50-450) Gravel washing or mining wastewater 10-50
Conductivity	micro-seimens/cm	• Discharge of most contaminants to water but particularly those high in nutrients or metals	Conductivity relates to the ability of a water sample to carry an electric current. This depends on the total concentration of ionised substances (minerals) dissolved in water and the temperature at which this measurement was made. Most contaminants will augment the conductivity of a water body, making this indicator widely applicable.	Seawater 50,000 Raw meat processing waste 5000-1000

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			Very little expense is required to obtain discrete conductivity measurements and real-time (in-situ, field) information is gained. Conductivity is not useful for compliance monitoring in the marine environment due to masking by high background concentrations.	Dairy shed ponds 2000-3000 Sewage oxidation ponds 200-400 Natural freshwater 40-70 (occasionally up to 100) Chlorinated tap water 100 Distilled water 2.0
pH	pH units	• Hard rock gold and coal mining • Klinker from cement processing • Concrete manufacturing and construction sites • Drainage of wetlands (e.g. humping and hollowing and v-blading)	pH (acidity and alkalinity) will impact upon freshwater ecosystems and may change through the course of a day. Particularly high (alkaline) or low (acidic) pH levels may have an adverse impact on aquatic biota directly. Alkaline conditions may also increase the toxicity of other pollutants such as ammonia-N, which in turn may adversely impact upon aquatic fauna (ANZECC, 1992). A sudden change outside the range of 6.5 – 8.5 may prove lethal to fish life in particular. Very little expense is required to obtain discrete pH measurements and real-time (in-situ, field) information is gained.	Battery acid 0-1 Vinegar 4-5 "Healthy" rivers 6.5-8.5 Some natural creeks draining pakihi as low as 4.5

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
				New Zealand Drinking Water Standards 7-8.5 Dairy shed effluent 7-8 Cement or lime 10-12 Chemical drain cleaner 14
Faecal Coliforms	Colony forming units/ 100ml	• Sewage or animal effluent discharge (treated or untreated)	Faecal coliforms are useful for determining the suitability of water for contact recreation, shellfish-gathering and stock drinking. The most common diseases associated with swimming areas are eye, ear, nose and throat infections, skin diseases and gastrointestinal disorders. A number of pathogens and parasites can be transmitted by contaminated water to livestock, which may result in reduced growth, morbidity or mortality. Faecal coliforms are indicator organisms only. This means their presence in water is indicative of harmful pathogens and not always harmful themselves. Measurement of harmful pathogens themselves is costly and can be impossible. Faecal coliforms are the preferred indicator for assessments of discharges from oxidation ponds/waste stabilisation ponds to marine or freshwater (L Sinton, ESR). In this context all the following indicators should be used in brackish water, or for sanitary surveys along the freshwater-marine continuum: faecal coliforms, *E. coli* and enterococci.	Oxidation pond effluent 10,000 Treated dairy shed effluent 100,000 Domestic sewage 10,000,000 Natural freshwater 30-90 New Zealand Drinking Water Standards 0

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
E. coli	Colony forming units/ 100ml	• Sewage or animal effluent discharge (treated or untreated)	*E. coli* are useful indicators in the freshwater environment. Environmental guidelines are available specific to this indicator. Their presence is indicative of pathogens harmful to human health.	Natural freshwater 1-50
Enterococci	Colony forming units/ 100ml	• Sewage or animal effluent discharge (treated or untreated)	Like *E. coli*, *Enterococci* are useful indicator bacteria but are more useful indicators in saline water than Faecal coliforms due to longer survival times. However, this indicator should not be used as the primary indicator for monitoring discharges from waste stabilisation ponds or oxidation ponds due to relatively high inactivation during this treatment process. Environmental guidelines are available specific to this indicator. Their presence is indicative of pathogens harmful to human health.	Natural saline water 1-10
Semi-Quantitative Macro-invertebrate Community Index (SQMCI and MCI), Total density, %EPT, number of EPT, Species Richness, Relative Abun-dance	SQMCI units	• Discharge of contaminants from most human activities will affect this indicator	Macroinvertebrates have been demonstrated in international and national studies to be a good indicator of water quality. However, habitat limiting factors such as: flow rates, warm temperatures, low dissolved oxygen, or smothering of the bed by sediment or algae also play a very important role. The use of this indicator can provide information on chronic environmental effects i.e. aggregated environmental effects of a contaminant discharge over an extended period (two to four weeks) preceding sampling. Chemical indicators only give the **potential** environmental effects, and unless large numbers of samples are taken over the whole 24 hour period and for several days/ weeks, the results can only be regarded as a very short "snapshot" in time.	Pristine rivers MCI = > 120 Good 100-120 Fair 80-100 Poor < 80 Number of taxa (kick net method) 20 (range 5-40) Number of taxa (surber sampling) 13-15

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			The macroinvertebrate community are generally more sensitive to **organic** pollution in comparison to the periphyton community. This is most often related to the dissolved oxygen of the water.	
Turbidity	NTU	Any land disturbance such as: • Mining/quarrying • Roadworks • Humping and hollowing • V-blading • Stockpiling of gravel and soil	Turbidity may be defined as the relative tendency of a water to scatter light. It is an important measure for two reasons: (a) a range of human activities' impact on turbidity; and (b) turbidity/water clarity is a key influence on the light climate and therefore the whole functioning of the aquatic ecosystem. Informally, turbidity is synonymous with cloudiness (lack of visual clarity). Changes in water clarity may be used to interpret the aesthetic values of waterways. Differences in water clarity also affect the ability of sight feeding predators, such as fish and birds, to locate prey and the ability of algae to photosynthesise and hence provide food for animals further up the food chain (Ministry for the Environment, 1994). Salmonids are known to avoid turbid water as low as 10 NTU. This indicator is particularly important in relation to alluvial gold mining and quarrying. It should be used in combination with suspended solids and visual clarity, as all these indicators are not always correlated.	Good quality drinking water <1NTU Noticeable cloudiness 5-10 Rivers in flood > 100 Dairy shed and sewage oxidation pond effluent 30 (Range often 10-150) Alluvial mining effluent 2000-4000 In very pristine waters discolouration may be detected when there is as little as a 2 NTU change.

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			Clay sized particles settle very slowly (typically 80-90mm/day).	
Periphyton % Cover	%	• Discharges with high concentrations of nutrients such as sewage or animal effluent discharge (treated or untreated)	Filamentous algae or "slime" in waterways has an adverse effect on aesthetic quality of streams and can lead to habitat effects for many stream organisms.	Filamentous algae: Pristine waters < 30% cover Moderate nutrient status 30%-50% High nutrient water >50% cover
Suspended Solids	g/m^3	• Land disturbance such as mining, roadworks, humping and hollowing, v-blading, stockpiling of gravel and soil	This is a measure of the materials in suspension in a water sample. Determined by filtration and weighing of dry material. Suspended solids affect colour, clarity, taste, as well as plant and animal life. Suspended solids may also cause an increase in temperature in the water body. Sediments may settle out and smother aquatic life or prevent light penetrating the water, preventing plant and algal growth. This indicator is particularly important in relation to alluvial gold mining and quarrying. It should be used in combination with turbidity and visual clarity, as all these indicators are not always correlated. Roughly linear relationship between suspended solids and	Good quality drinking water < 5 Natural freshwater 0.5-1.0 Rivers in flood 200-300 Oxidation pond effluent 50-150 Domestic sewage 200-300

Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
			turbidity (particle size dependent).	
Nutrients			Nutrient concentrations usually peak just before the peak flow in a flood situation and in autumn. Lowest levels of nutrients are generally in mid-summer.	
Dissolved Reactive Phosphorus (DRP)	g/m^3	• Fertilising operations on farms	Dissolved reactive phosphorous (DRP) is a form of phosphate that is available immediately for plant growth (ANZECC, 1992). DRP levels in water samples are often inversely related to periphyton cover (predominantly attached algae) due to uptake of the nutrient by periphyton (Smith et al., 1993).	Above 0.15-0.03 eutrophication likely to occur. (However, other factors such as substrate stability, sunlight and temperature may affect plant growth.)
Nitrate-N (NO_3-N)	g/m^3	• Fertilising operations on farms, sewage/manure waste discharges, landfills	Nitrate-N is mainly derived from land and subsoil drainage. Elevated nitrate levels can occur naturally, or as a result of human activity. Nitrate is an important nutrient for the growth of algae and other plants and may be harmful to stock in sufficient concentrations (ANZECC, 1992). Nitrate can be converted within animals and organisms to nitrite as a result of bacterial reduction. In infants the conversion of nitrate to nitrite is high, therefore it can combine with haemoglobin to form metahaemoglobin, resulting in a reduction of oxygen transport capacity in the blood (ANZECC, 1992). If most of nitrogen in the sampled water is in the nitrate form, it may indicate pollution from events several weeks prior to sampling. This is due to degradation of ammonia through denitrification.	Natural range 0.02 - 0.1 WHO Drinking water limit 10

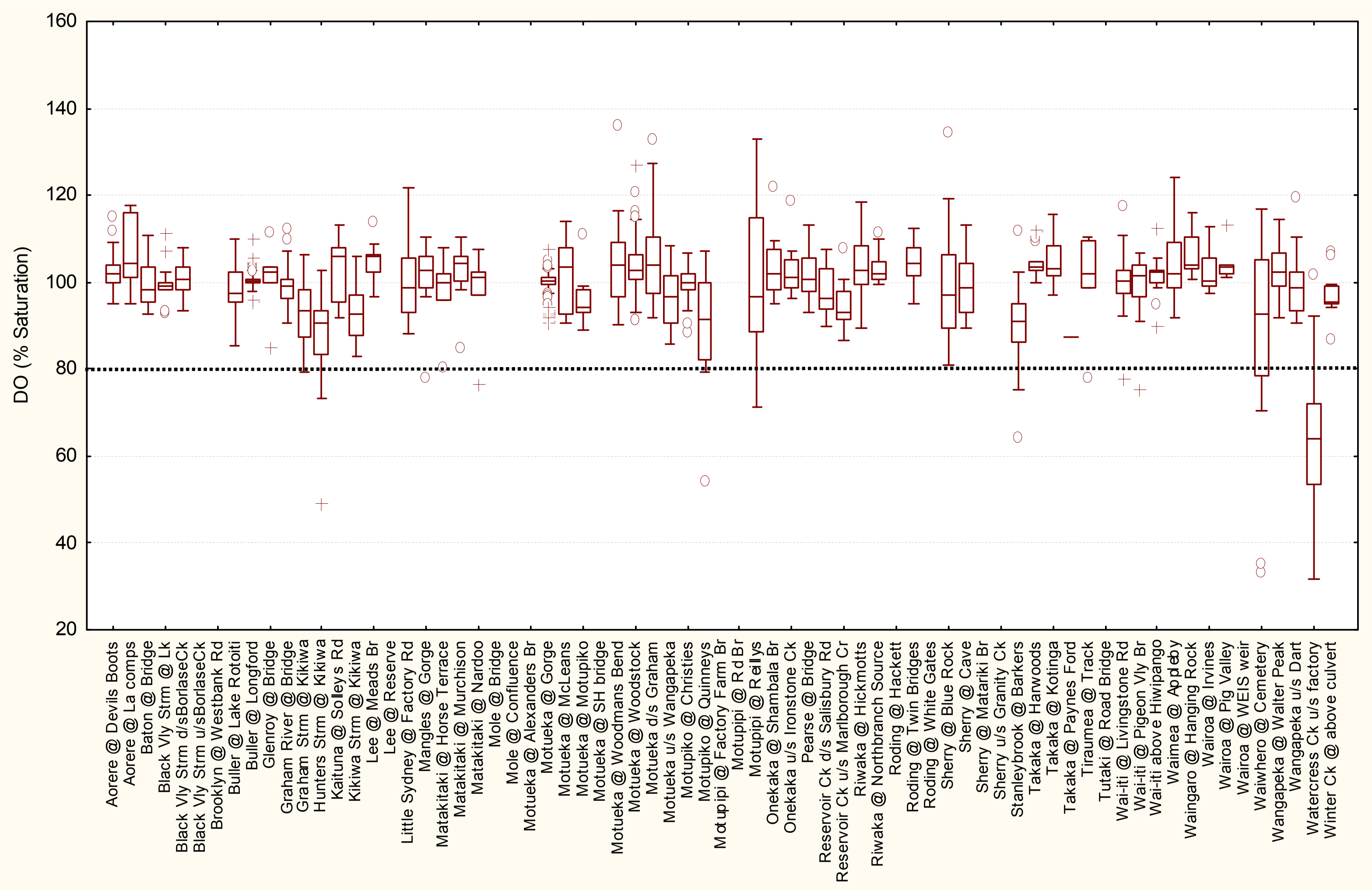
Indicator	Units	Environmental Pressures Influencing the Indicator Level	Application	Typical Examples
Dissolved Inorganic Nitrogen	g/m^3	•	Dissolved Inorganic Nitrogen is a measure of the nitrogen available to plants. Dissolved Inorganic Nitrogen = (ammonia-N + nitrate-N) (ANZECC, 1992).	Natural range 0.01-0.03 Above 0.04-0.10 eutrophication likely to occur (However, other factors such as substrate stability, sunlight and temperature may affect plant growth.)

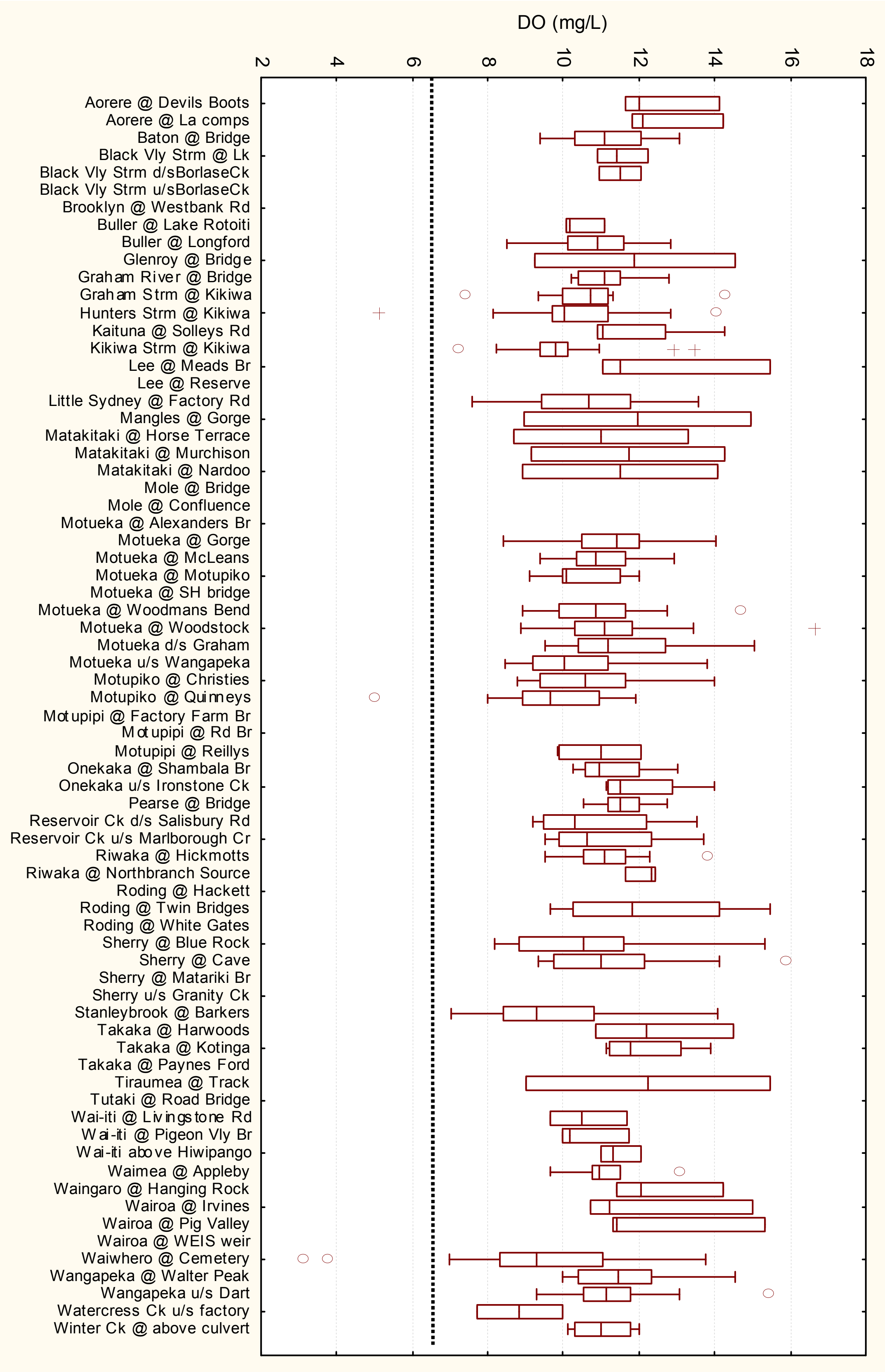
APPENDIX 4

Box Plot Summaries of Water Quality at Each Site

Appendix 4: Box Plot Summaries of Water Quality Data From Each Site

Each box encloses 50% of the data, with the median shown as a horizontal bar. Lines extending from the top and bottom of each box mark the minimum and maximum values that fall within an acceptable range (1.5* the size of the box). Outliers are marked with an open circle, and extreme values (>3* the size of the box) are marked with a cross. Note that the y-axis for some variables is on a log scale. Relevant water quality guidelines are shown with dotted lines where appropriate.




DO (mg/L)
2
4
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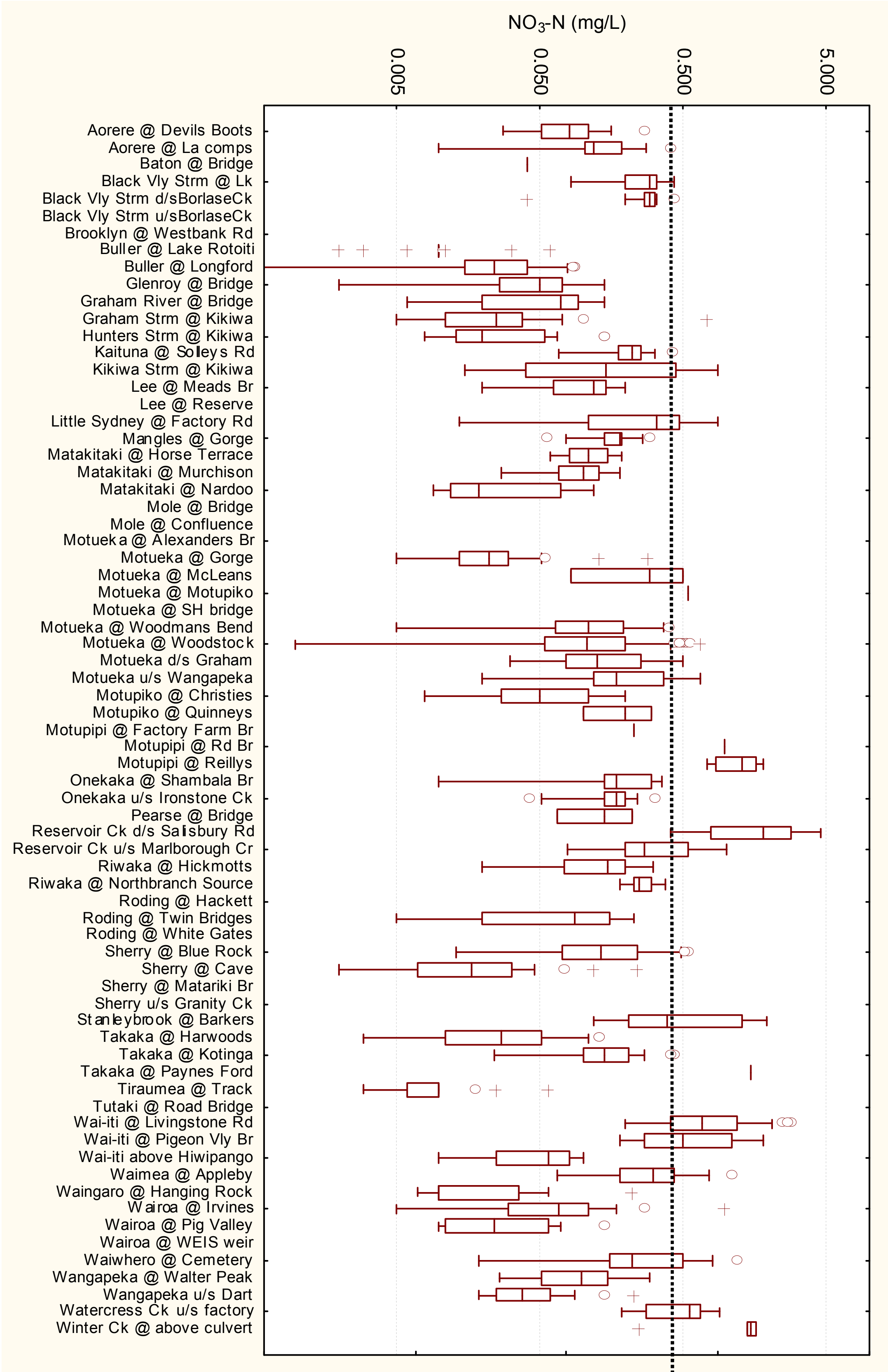
8
10
12
14
16
18
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert

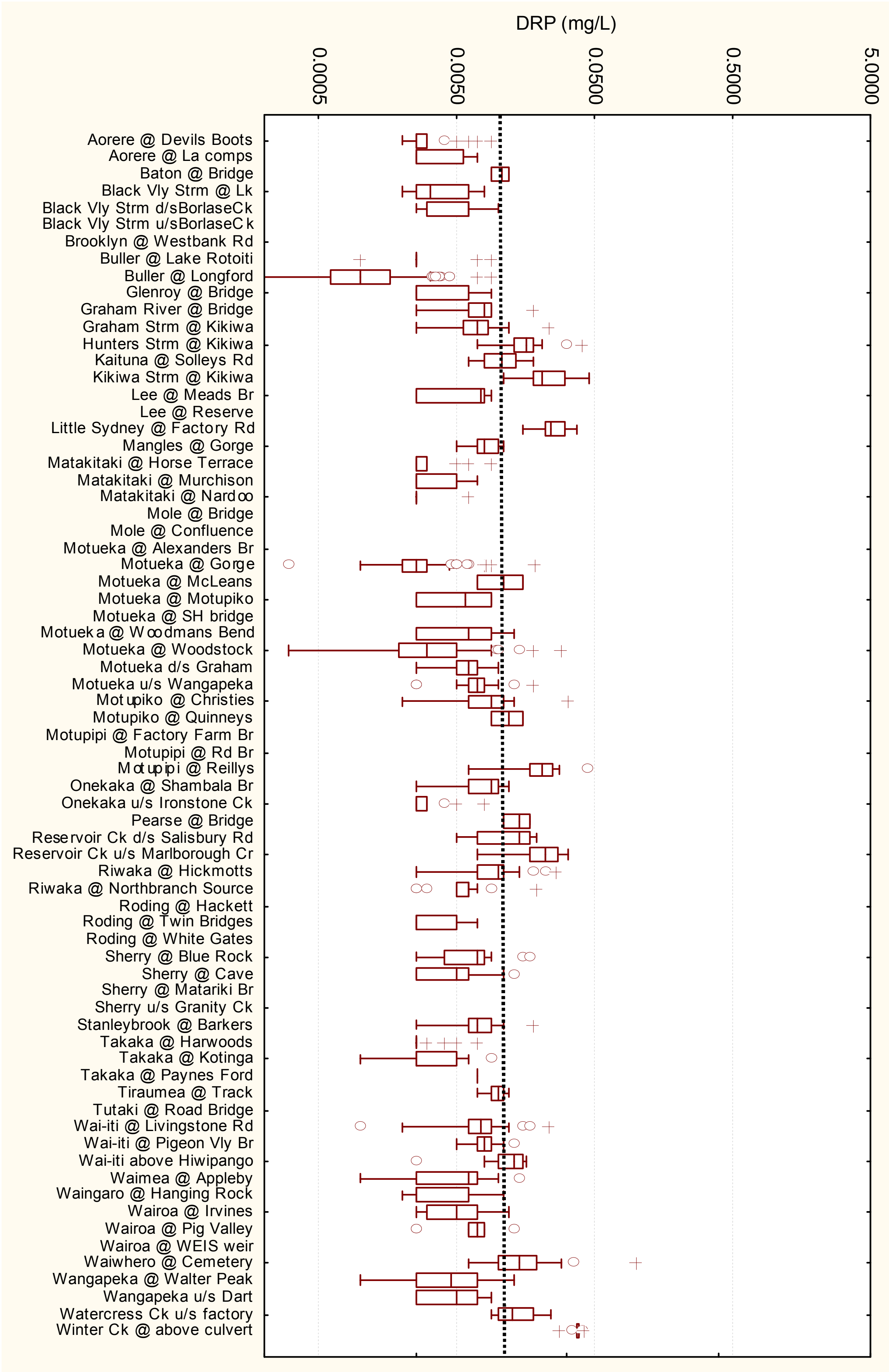

pH
4
5
6
7
8
9
10
11
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


Conductivity (µS/cm)
0
100
200
300
400
500
600
700
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


TN (mg/L)
0.05
0.50
5.00
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


NO3-N (mg/L)
0.005
0.050
0.500
5.000
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Soleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


NH4-N (mg/L)
0.005
0.050
0.500
5.000
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


DRP (mg/L)
0.0005
0.0050
0.0500
0.5000
5.0000
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
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Onekaka u/s Ironstone Ck
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Reservoir Ck u/s Marlborough Cr
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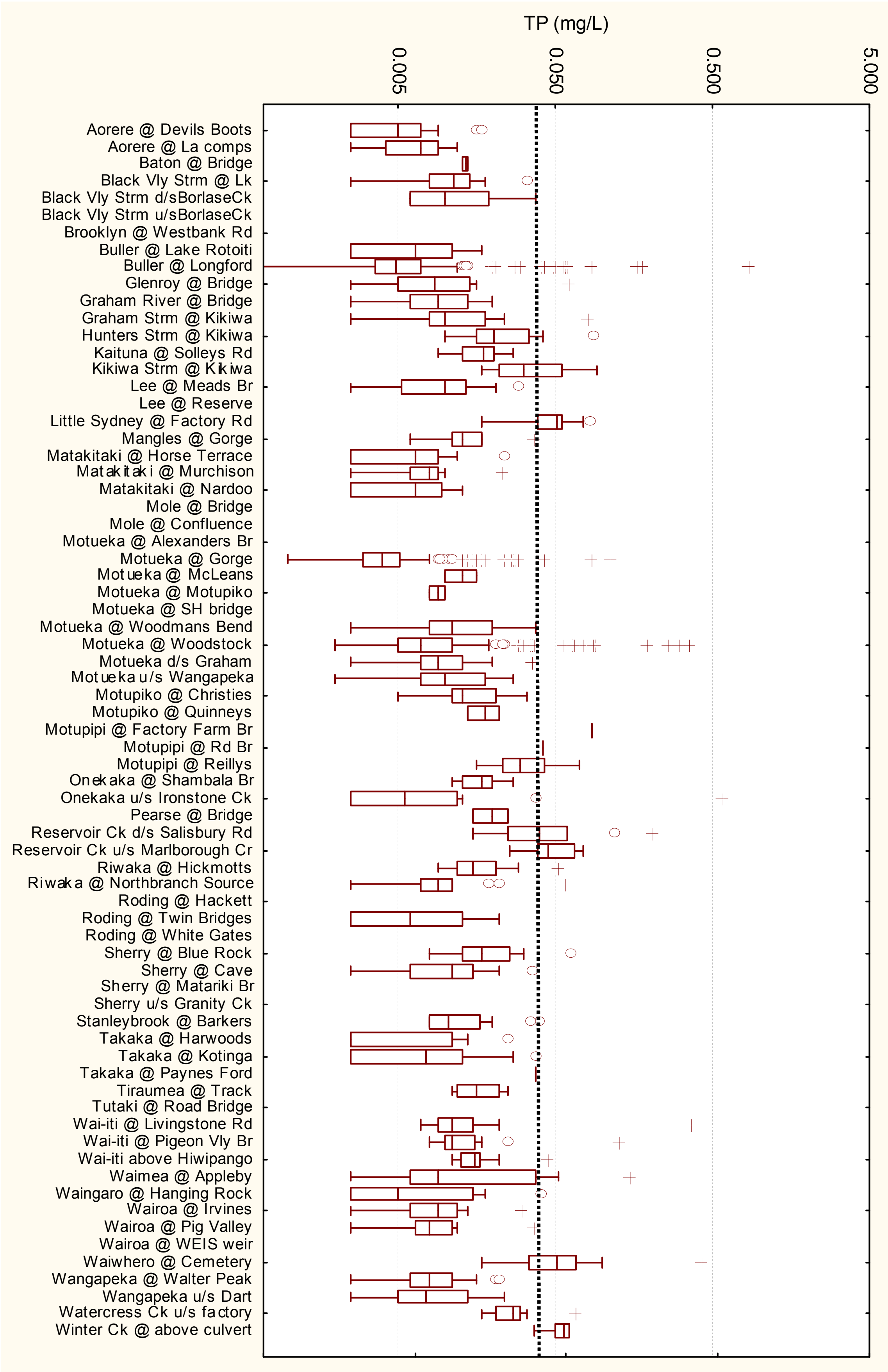
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert



TP (mg/L)
0.005
0.050
0.500
5.000
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


E. coli (cfu/100 mL)
5
50
500
5000
Acceptable
Alert
Action
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert

Clarity (m)
0
5
10
15
20
25
30
35
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
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Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
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Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
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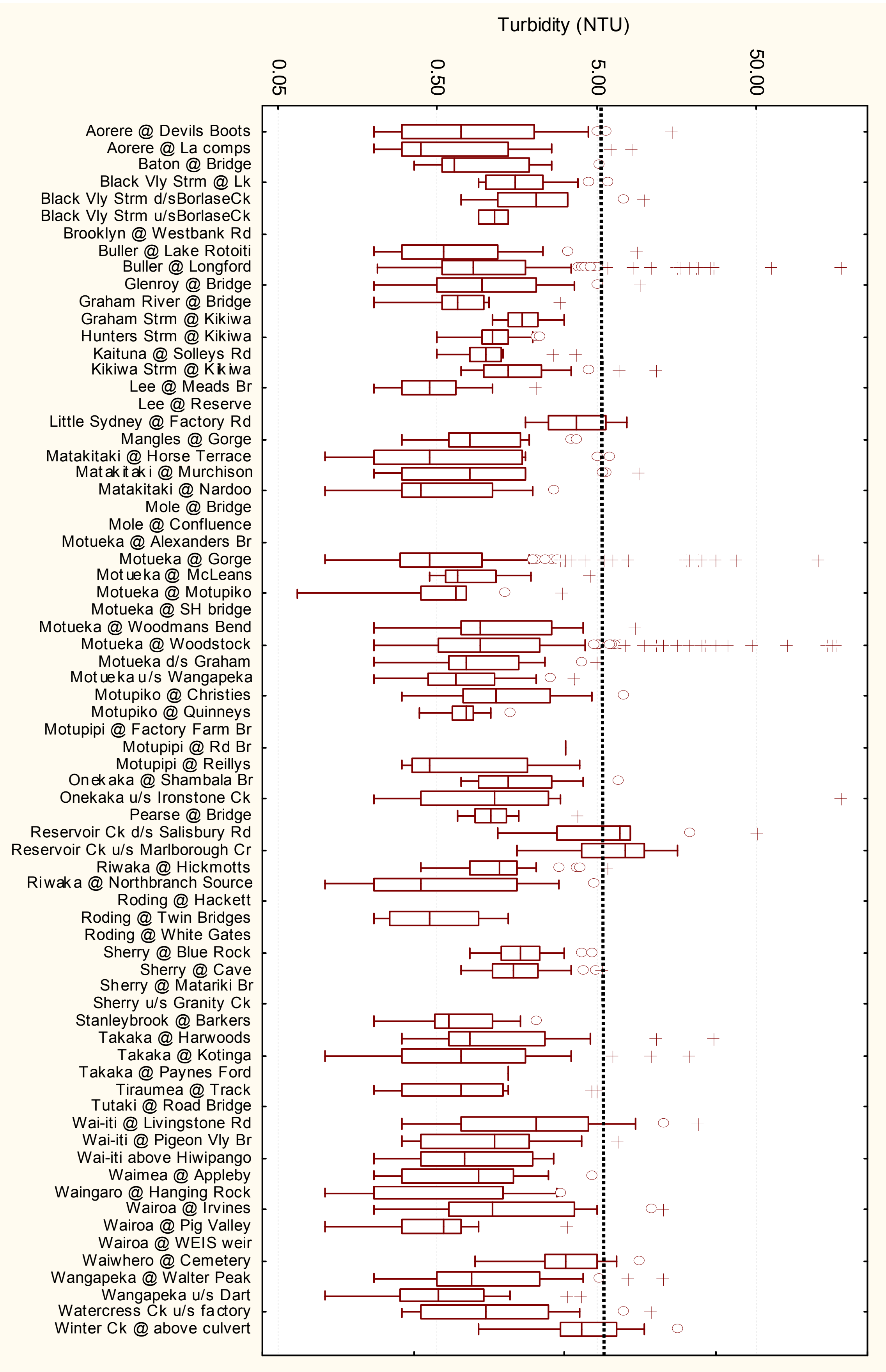
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


Turbidity (NTU)
0.05
0.50
5.00
50.00
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert

TSS (mg/L)
0.25
0.50
0.75
2.50
5.00
7.50
25.00
50.00
75.00
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
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Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert


FSS (mg/L)
0.25
0.50
0.75
2.50
5.00
7.50
25.00
50.00
75.00
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
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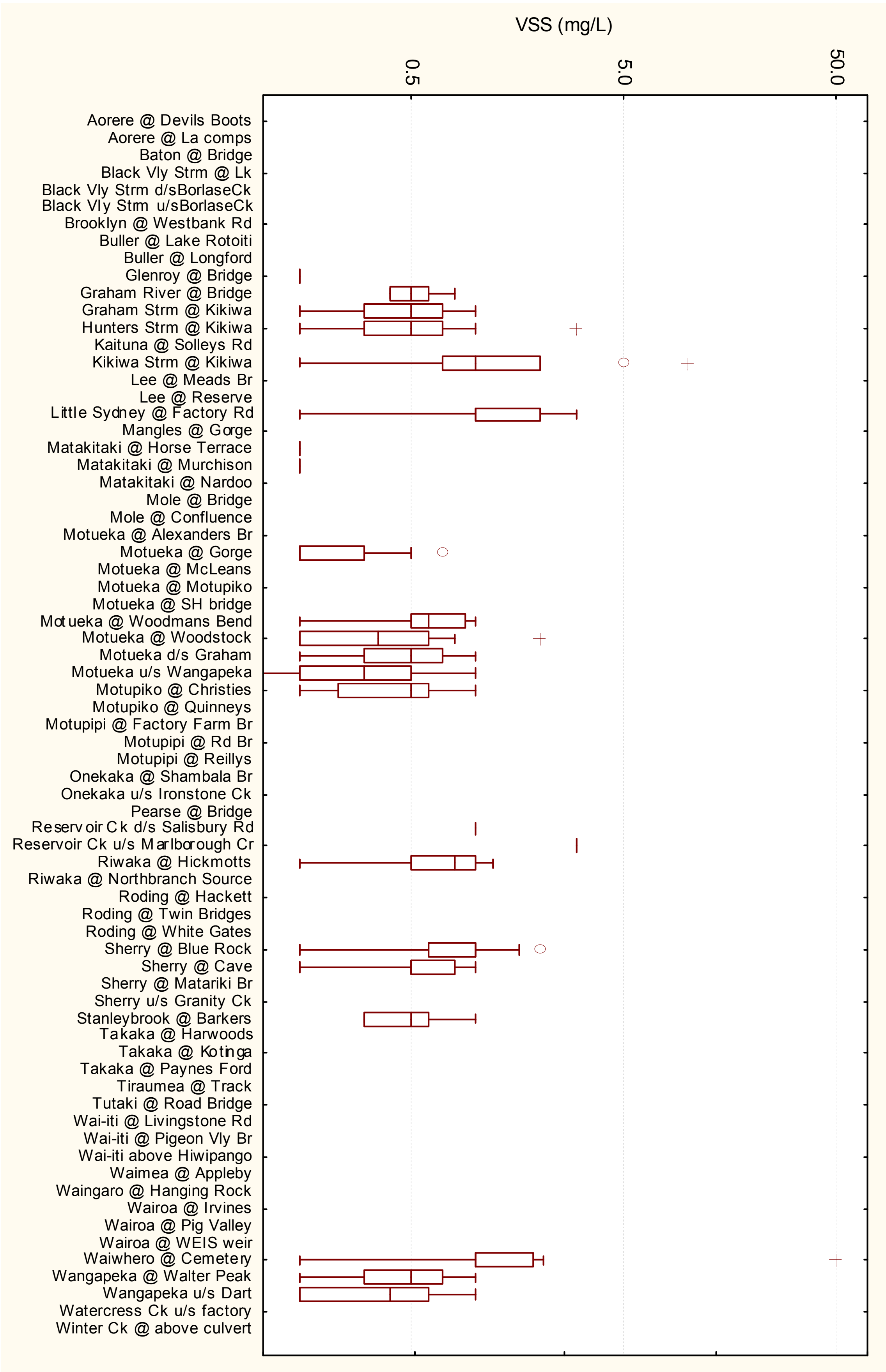
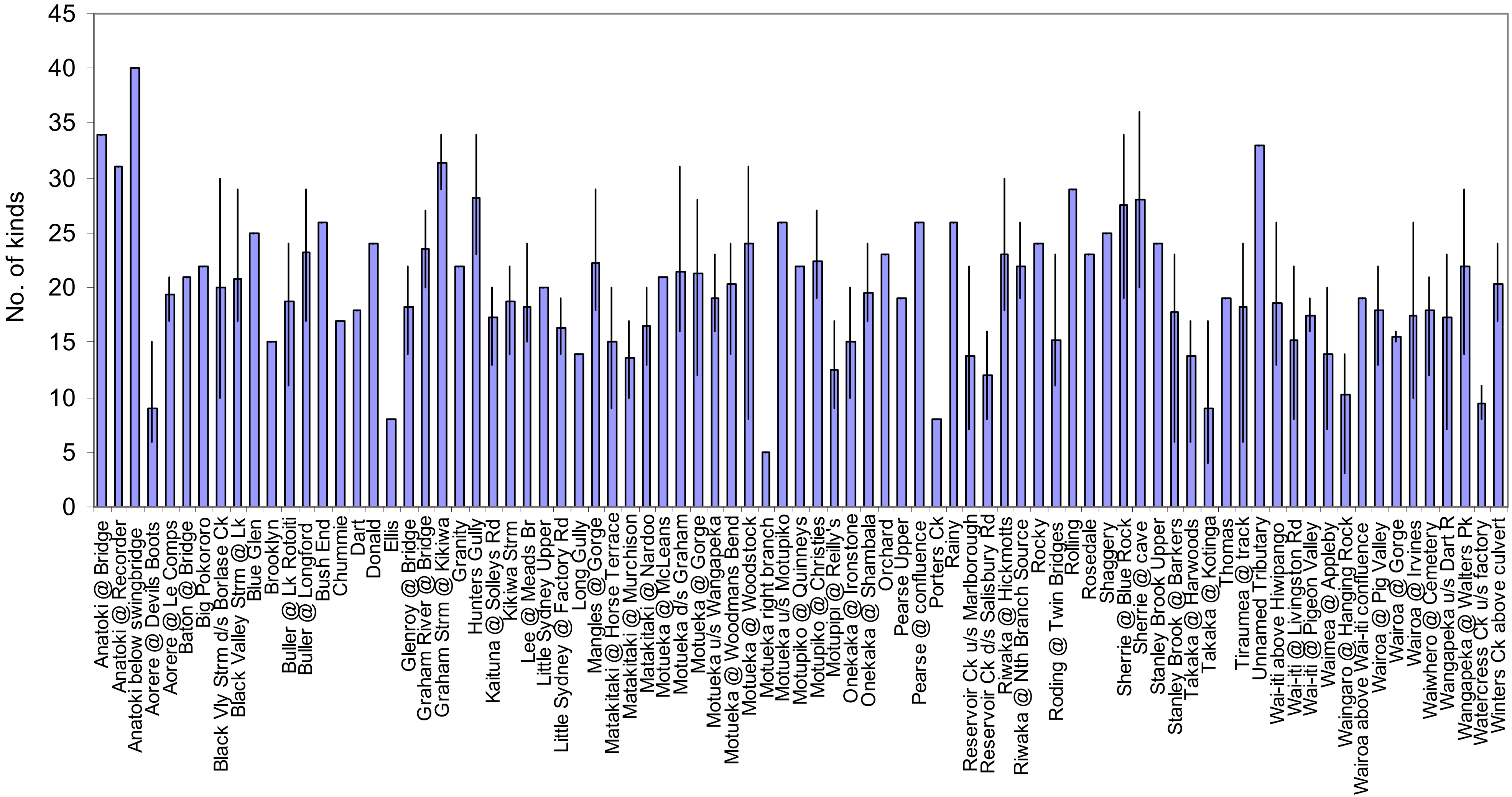
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert

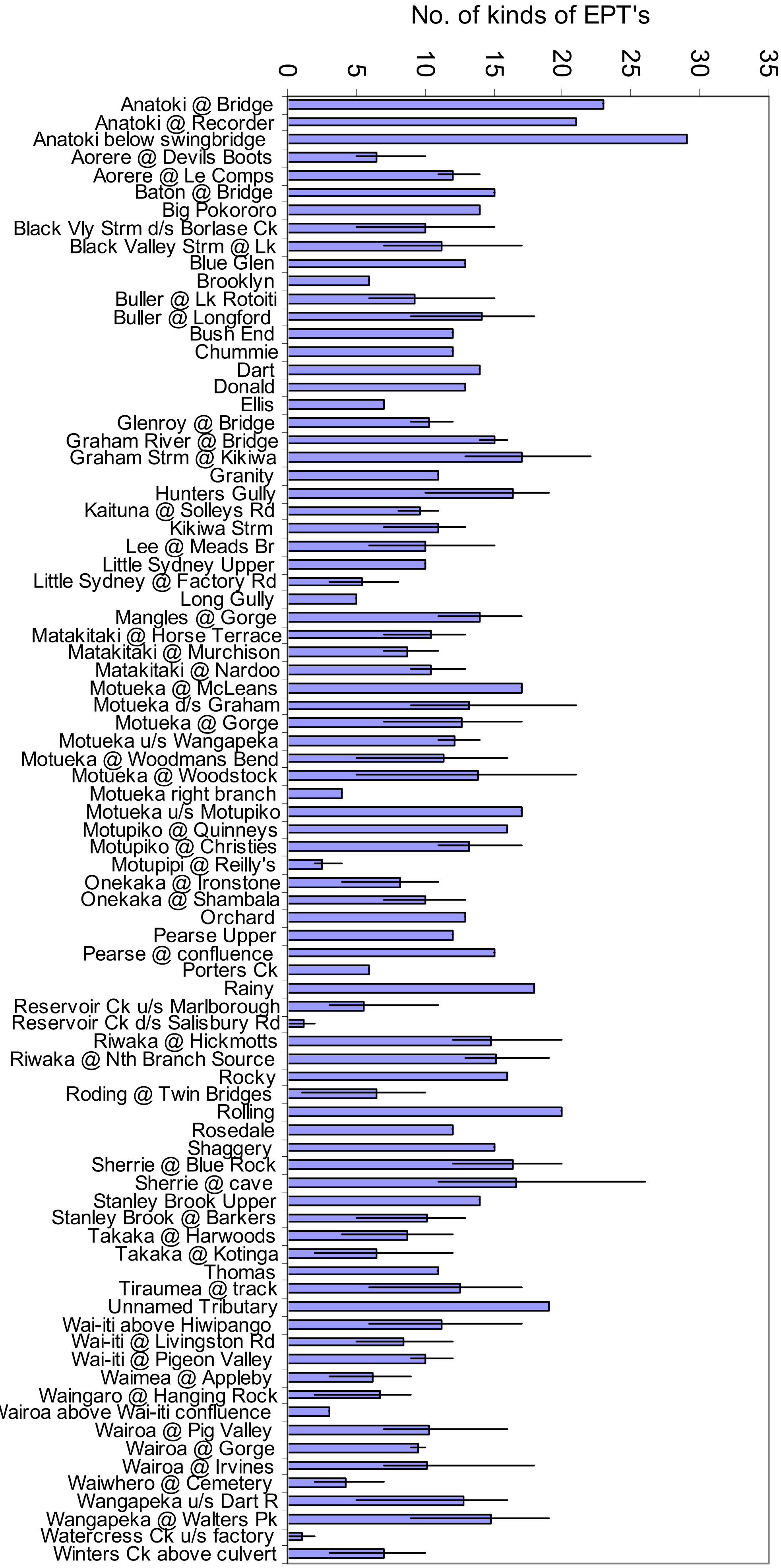

VSS (mg/L)
0.5
5.0
50.0
Aorere @ Devils Boots
Aorere @ La comps
Baton @ Bridge
Black Vly Strm @ Lk
Black Vly Strm d/sBorlaseCk
Black Vly Strm u/sBorlaseCk
Brooklyn @ Westbank Rd
Buller @ Lake Rotoiti
Buller @ Longford
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Hunters Strm @ Kikiwa
Kaituna @ Solleys Rd
Kikiwa Strm @ Kikiwa
Lee @ Meads Br
Lee @ Reserve
Little Sydney @ Factory Rd
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Mole @ Bridge
Mole @ Confluence
Motueka @ Alexanders Br
Motueka @ Gorge
Motueka @ McLeans
Motueka @ Motupiko
Motueka @ SH bridge
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka d/s Graham
Motueka u/s Wangapeka
Motupiko @ Christies
Motupiko @ Quinneys
Motupipi @ Factory Farm Br
Motupipi @ Rd Br
Motupipi @ Reillys
Onekaka @ Shambala Br
Onekaka u/s Ironstone Ck
Pearse @ Bridge
Reservoir Ck d/s Salisbury Rd
Reservoir Ck u/s Marlborough Cr
Riwaka @ Hickmotts
Riwaka @ Northbranch Source
Roding @ Hackett
Roding @ Twin Bridges
Roding @ White Gates
Sherry @ Blue Rock
Sherry @ Cave
Sherry @ Matariki Br
Sherry u/s Granity Ck
Stanleybrook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Takaka @ Paynes Ford
Tiraumea @ Track
Tutaki @ Road Bridge
Wai-iti @ Livingstone Rd
Wai-iti @ Pigeon Vly Br
Wai-iti above Hiwipango
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa @ Irvines
Wairoa @ Pig Valley
Wairoa @ WEIS weir
Waiwhero @ Cemetery
Wangapeka @ Walter Peak
Wangapeka u/s Dart
Watercress Ck u/s factory
Winter Ck @ above culvert

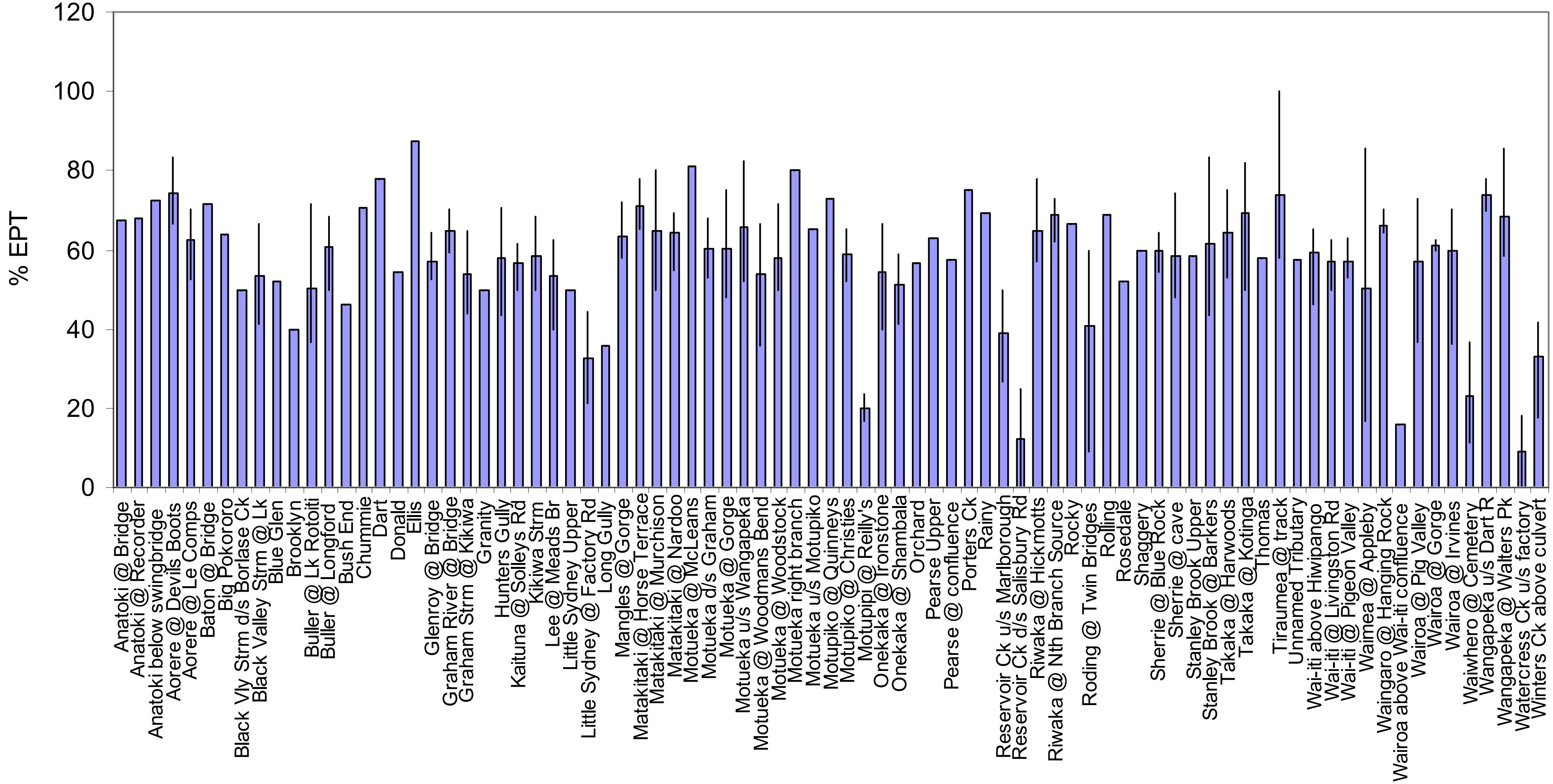
APPENDIX 5

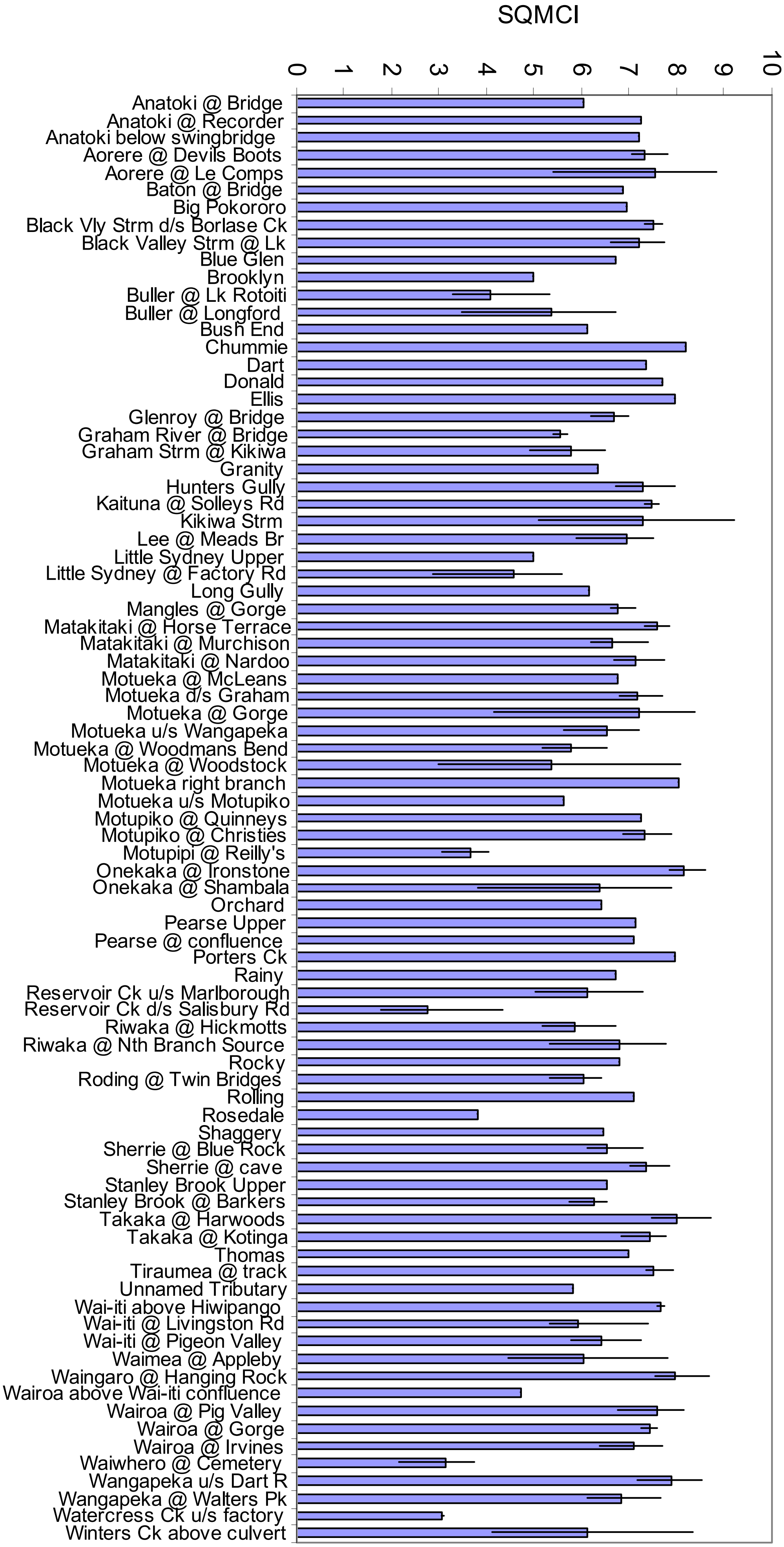
Mean and Range of Invertebrate Indices at Each Site

Appendix 5: Mean and Range of Macroinvertebrate Indices Calculated From Data at Each Site




No. of kinds of EPT's
0
5
10
15
20
25
30
35
Anatoki @ Bridge
Anatoki @ Recorder
Anatoki below swingbridge
Aorere @ Devils Boots
Aorere @ Le Comps
Baton @ Bridge
Big Pokororo
Black Vly Strm d/s Borlase Ck
Black Valley Strm @ Lk
Blue Glen
Brooklyn
Buller @ Lk Rotoiti
Buller @ Longford
Bush End
Chummie
Dart
Donald
Ellis
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Granity
Hunters Gully
Kaituna @ Solleys Rd
Kikiwa Strm
Lee @ Meads Br
Little Sydney Upper
Little Sydney @ Factory Rd
Long Gully
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Motueka @ McLeans
Motueka d/s Graham
Motueka @ Gorge
Motueka u/s Wangapeka
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka right branch
Motueka u/s Motupiko
Motupiko @ Quinneys
Motupiko @ Christies
Motupipi @ Reilly's
Onekaka @ Ironstone
Onekaka @ Shambala
Orchard
Pearse Upper
Pearse @ confluence
Porters Ck
Rainy
Reservoir Ck u/s Marlborough
Reservoir Ck d/s Salisbury Rd
Riwaka @ Hickmotts
Riwaka @ Nth Branch Source
Rocky
Roding @ Twin Bridges
Rolling
Rosedale
Shaggery
Sherrie @ Blue Rock
Sherrie @ cave
Stanley Brook Upper
Stanley Brook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Thomas
Tiraumea @ track
Unnamed Tributary
Wai-iti above Hiwipango
Wai-iti @ Livingston Rd
Wai-iti @ Pigeon Valley
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa above Wai-iti confluence
Wairoa @ Pig Valley
Wairoa @ Gorge
Wairoa @ Irvines
Waiwhero @ Cemetery
Wangapeka u/s Dart R
Wangapeka @ Walters Pk
Watercress Ck u/s factory
Winters Ck above culvert


% EPT
0
20
40
60
80
100
120
Anatoki @ Bridge
Anatoki @ Recorder
Anatoki below swingbridge
Aorere @ Devils Boots
Aorere @ Le Comps
Baton @ Bridge
Big Pokororo
Black Vly Strm d/s Borlase Ck
Black Valley Strm @ Lk
Blue Glen
Brooklyn
Buller @ Lk Rotoiti
Buller @ Longford
Bush End
Chummie
Dart
Donald
Ellis
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Granity
Hunters Gully
Kaituna @ Solleys Rd
Kikiwa Strm
Lee @ Meads Br
Little Sydney Upper
Little Sydney @ Factory Rd
Long Gully
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Motueka @ McLeans
Motueka d/s Graham
Motueka @ Gorge
Motueka u/s Wangapeka
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka right branch
Motueka u/s Motupiko
Motupiko @ Quinneys
Motupiko @ Christies
Motupipi @ Reilly's
Onekaka @ Ironstone
Onekaka @ Shambala
Orchard
Pearse Upper
Pearse @ confluence
Porters Ck
Rainy
Reservoir Ck u/s Marlborough
Reservoir Ck d/s Salisbury Rd
Riwaka @ Hickmotts
Riwaka @ Nth Branch Source
Rocky
Roding @ Twin Bridges
Rolling
Rosedale
Shaggery
Sherrie @ Blue Rock
Sherrie @ cave
Stanley Brook Upper
Stanley Brook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Thomas
Tiraumea @ track
Unnamed Tributary
Wai-iti above Hiwipango
Wai-iti @ Livingston Rd
Wai-iti @ Pigeon Valley
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa above Wai-iti confluence
Wairoa @ Pig Valley
Wairoa @ Gorge
Wairoa @ Irvines
Waiwhero @ Cemetery
Wangapeka u/s Dart R
Wangapeka @ Walters Pk
Watercress Ck u/s factory
Winters Ck above culvert


SQMCI
0
1
2
3
4
5
6
7
8
9
10
Anatoki @ Bridge
Anatoki @ Recorder
Anatoki below swingbridge
Aorere @ Devils Boots
Aorere @ Le Comps
Baton @ Bridge
Big Pokororo
Black Vly Strm d/s Borlase Ck
Black Valley Strm @ Lk
Blue Glen
Brooklyn
Buller @ Lk Rotoiti
Buller @ Longford
Bush End
Chummie
Dart
Donald
Ellis
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Granity
Hunters Gully
Kaituna @ Solleys Rd
Kikiwa Strm
Lee @ Meads Br
Little Sydney Upper
Little Sydney @ Factory Rd
Long Gully
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Motueka @ McLeans
Motueka d/s Graham
Motueka @ Gorge
Motueka u/s Wangapeka
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka right branch
Motueka u/s Motupiko
Motupiko @ Quinneys
Motupiko @ Christies
Motupipi @ Reilly's
Onekaka @ Ironstone
Onekaka @ Shambala
Orchard
Pearse Upper
Pearse @ confluence
Porters Ck
Rainy
Reservoir Ck u/s Marlborough
Reservoir Ck d/s Salisbury Rd
Riwaka @ Hickmotts
Riwaka @ Nth Branch Source
Rocky
Roding @ Twin Bridges
Rolling
Rosedale
Shaggery
Sherrie @ Blue Rock
Sherrie @ cave
Stanley Brook Upper
Stanley Brook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Thomas
Tiraumea @ track
Unnamed Tributary
Wai-iti above Hiwipango
Wai-iti @ Livingston Rd
Wai-iti @ Pigeon Valley
Waimea @ Appleby
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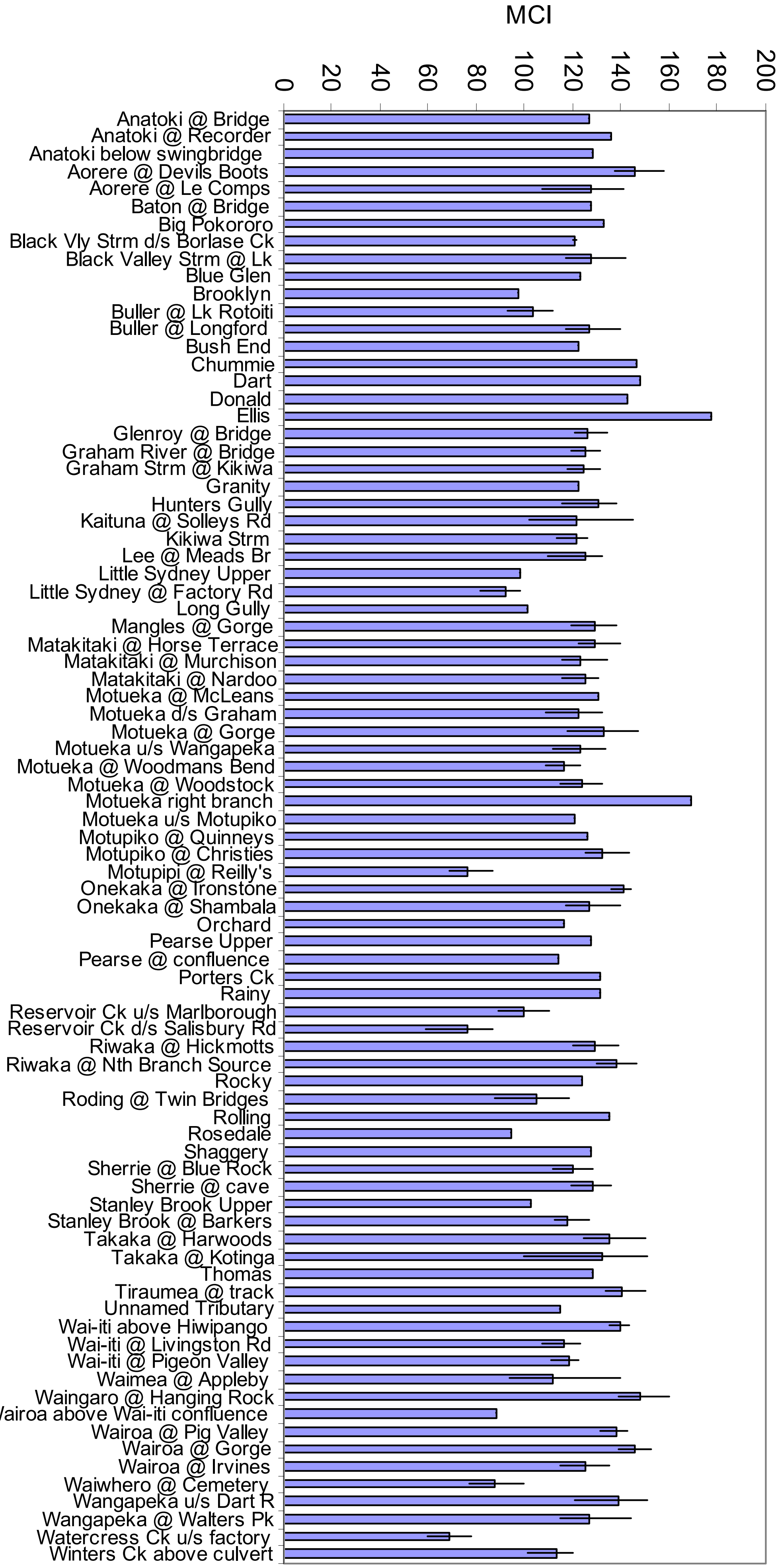
Wairoa above Wai-iti confluence
Wairoa @ Pig Valley
Wairoa @ Gorge
Wairoa @ Irvines
Waiwhero @ Cemetery
Wangapeka u/s Dart R
Wangapeka @ Walters Pk
Watercress Ck u/s factory
Winters Ck above culvert


MCI
0
20
40
60
80
100
120
140
160
180
200
Anatoki @ Bridge
Anatoki @ Recorder
Anatoki below swingbridge
Aorere @ Devils Boots
Aorere @ Le Comps
Baton @ Bridge
Big Pokororo
Black Vly Strm d/s Borlase Ck
Black Valley Strm @ Lk
Blue Glen
Brooklyn
Buller @ Lk Rotoiti
Buller @ Longford
Bush End
Chummie
Dart
Donald
Ellis
Glenroy @ Bridge
Graham River @ Bridge
Graham Strm @ Kikiwa
Granity
Hunters Gully
Kaituna @ Solleys Rd
Kikiwa Strm
Lee @ Meads Br
Little Sydney Upper
Little Sydney @ Factory Rd
Long Gully
Mangles @ Gorge
Matakitaki @ Horse Terrace
Matakitaki @ Murchison
Matakitaki @ Nardoo
Motueka @ McLeans
Motueka d/s Graham
Motueka @ Gorge
Motueka u/s Wangapeka
Motueka @ Woodmans Bend
Motueka @ Woodstock
Motueka right branch
Motueka u/s Motupiko
Motupiko @ Quinneys
Motupiko @ Christies
Motupipi @ Reilly's
Onekaka @ Ironstone
Onekaka @ Shambala
Orchard
Pearse Upper
Pearse @ confluence
Porters Ck
Rainy
Reservoir Ck u/s Marlborough
Reservoir Ck d/s Salisbury Rd
Riwaka @ Hickmotts
Riwaka @ Nth Branch Source
Rocky
Roding @ Twin Bridges
Rolling
Rosedale
Shaggery
Sherrie @ Blue Rock
Sherrie @ cave
Stanley Brook Upper
Stanley Brook @ Barkers
Takaka @ Harwoods
Takaka @ Kotinga
Thomas
Tiraumea @ track
Unnamed Tributary
Wai-iti above Hiwipango
Wai-iti @ Livingston Rd
Wai-iti @ Pigeon Valley
Waimea @ Appleby
Waingaro @ Hanging Rock
Wairoa above Wai-iti confluence
Wairoa @ Pig Valley
Wairoa @ Gorge
Wairoa @ Irvines
Waiwhero @ Cemetery
Wangapeka u/s Dart R
Wangapeka @ Walters Pk
Watercress Ck u/s factory
Winters Ck above culvert