**BEFORE THE INDEPENDENT COMMISSIONERS**

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| **IN THE MATTER** | of the Resource Management Act 1991 |
| **AND** | |
| **IN THE MATTER** | of the Proposed Canterbury Land and Water Regional Plan |

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# EVIDENCE IN CHIEF OF ROGER GRAEME YOUNG ON BEHALF OF NELSON/MARLBOROUGH, NORTH CANTERBURY AND CENTRAL SOUTH ISLAND FISH AND GAME COUNCILS

**4 FEBRUARY 2013**

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**QUALIFICATIONS AND EXPERIENCE**

1. My name is Roger Graeme Young. I am a freshwater ecologist and have been employed at the Cawthron Institute in Nelson for the last 15 years. I have the following qualifications: BSc Honours and PhD in Zoology from the University of Otago. I am a member of the New Zealand Freshwater Sciences Society and the Society for Freshwater Science (formerly North American Benthological Society).

2. My areas of expertise include freshwater fisheries, river health assessment, water quality, and river ecosystem ecology.

3. Over the last 15 years I have undertaken freshwater ecological work throughout New Zealand for clients including power companies, regional councils, Ministry for the Environment, Department of Conservation and Fish and Game New Zealand. I have also been involved with research investigating new tools for river health assessment, the behavioural response of back country trout to anglers, integrated catchment management, factors affecting trout abundance, relationships between human pressure indicators and aquatic ecosystem integrity, accuracy of drift dive assessments of trout abundance, catchment-wide patterns of fish movement, and tools for rehabilitating river ecosystems. I have written 44 scientific papers and more than 60 reports relating to this work.

4. Examples of recent hearings in which I have presented water quality, freshwater fisheries, river ecology and instream habitat evidence include:
    a. Canterbury Regional Council hearing relating to the proposed Hurunui and Waiau River Regional Plan;
    b. The special tribunal hearing related to the application to amend the National Water Conservation (Rakaia River) Order 1988;
    c. Environment Court hearing on Horizons Regional Council One Plan;
    d. Environment Canterbury's hearing on their proposed Canterbury Regional Policy Statement;

e. Horizons Regional Council hearing on their proposed One Plan;

f. The special tribunal hearing on behalf of Fish and Game NZ – North Canterbury Region on their application for the Hurunui River Water Conservation Order; and

g. Meridian Energy's lower Waitaki North Branch Tunnel Concept Water Resource Consents Hearing.

5. I have recently been appointed to a science panel to assist with the development of a national objectives framework to help with limit setting, as required under the National Policy Statement for Freshwater Management.

6. In preparing this evidence I have reviewed:

a. Fish and Game's submission;

b. Associate Professor Death's evidence on behalf of Fish and Game;

c. Ross Millichamp's evidence on behalf of Fish and Game;

d. Proposed Canterbury Land and Water Regional Plan (pCLWRP) Section 42A Report Volume 1 for Hearing Group 1; and

e. Provisions of the pCLWRP.

7. I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note. This evidence has been prepared in accordance with it and I agree to comply with it. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

## SCOPE OF EVIDENCE

8. I have been asked by Nelson Marlborough, North Canterbury and Central South Island Fish and Game Councils ("Fish and Game") to prepare evidence in relation to the proposed Canterbury Land and Water Regional Plan ("pCLWRP"). This includes information on:

a. State and trends in water quality in the Canterbury region;

b. Factors affecting water quality in Canterbury;

c. Environmental flow regimes and approaches for managing water allocation while maintaining instream values; and

d. Limits that could be used to protect key values identified in the Canterbury Region.

**EXECUTIVE SUMMARY**

9. Ecosystem health, recreational values, stock water drinking and human consumption are all affected by poor water quality. Therefore, water quality limits are required to help maintain the life supporting capacity and values that are supported by waterways.

10. Management units have been proposed for waterbodies throughout the Canterbury Region by Hayward et al. (2009). This report also identified management purposes for each of these waterbody management units. However, the pCLWRP has omitted to include these management purposes or objectives. Without identification of the values supported by waterbodies within each management unit, freshwater limits cannot be set.

11. Water quality is very good in rivers and streams draining natural state and alpine areas, which reflects the low intensity of land development in these areas. However, there are indications of downstream increases in the concentrations of suspended solids, nitrogen, phosphorus and faecal indicator bacteria in the lower reaches of the large alpine rivers, which is a signal of inputs from developed land in the lower reaches of these systems. Water quality of lake-fed and hill-fed rivers and streams is also generally good with cool water temperatures, adequate dissolved oxygen, and low concentrations of suspended solids and faecal indicator bacteria. Streams draining Banks Peninsula have reasonable water quality, but concentrations of suspended solids, dissolved phosphorus and faecal indicator bacteria are elevated. Streams draining lowland parts of Canterbury generally have poor water quality with low concentrations of dissolved oxygen, poor water clarity and high concentrations of faecal indicator bacteria and dissolved phosphorus and nitrogen.

12. High country lakes in Canterbury generally have good water quality with low concentrations of nutrients and phytoplankton. In contrast, lowland lakes in Canterbury, such as Ellesmere/Te Waihora and Forsyth/Te Roto o Wairewa, suffer from high concentrations of nutrients, phytoplankton and suspended solids. Lake Forsyth/Te Roto o Wairewa experiences toxic cyanobacterial blooms in most summers that endanger aquatic life, stock, dogs and potentially people that wish to recreate on or near the lake. Warning signs are erected at the lake advising people to avoid contact with the lake during blooms.

13. Trend analyses indicated that there have been statistically significant increases in total nitrogen concentration at 8 of the 10 sites that have been monitored monthly over the last 24 years. Phosphorus concentrations increased at three sites and decreased at two sites. The pattern of increasing concentration of nutrients that has been observed in these Canterbury rivers has also been observed elsewhere around New Zealand and is consistent with pastoral expansion and intensification and the increased use of nitrogenous fertilisers.

14. The poor state of Canterbury's lowland rivers and lakes is a serious concern and appears to be getting worse. Ecosystem health in many of these systems is degraded and needs severe and urgent attention if it is to be improved.

15. The MfE Flow Guidelines for Instream Values (1998) state that there are two critical parameters of a flow regime that need to be prescribed for sustaining instream values: 1) a minimum flow to fulfil water quality and habitat requirements, and 2) flow variability for maintenance of natural character, channel form, sediment and periphyton flushing, benthic invertebrate productivity, fish and bird feeding opportunities, and fishing opportunities.

16. Annual or seasonal minimum flows are required for maintaining instream habitats, while allocation limits, or flow sharing rules, are required for maintaining flow variability.

17. The mean annual low flow ("MALF") is an important controller of fish habitat, while invertebrate habitat is primarily controlled by the median flow. This rationale underpins the common practice of referencing minimum flow decisions on New Zealand rivers to fish habitat available at the MALF, and benthic invertebrate habitat to the median flow.

18. A flow of three times the median flow is generally considered to the large enough to effectively flush periphyton and deposited detritus from the river bed. Therefore, maintenance of the frequency of flows of this size ("FRE3") should be an important objective in water management. Maintenance of the frequency of larger floods responsible for forming and maintaining the river channel is also important. In Canterbury rivers, maintaining the frequency of flows that are sufficient to open the river mouths is also an important consideration.

19. When assessing and setting an environmental flow regime, the flow statistics on which they are based ought to be naturalised (i.e. the natural MALF), rather than based on measured river flows, which may be strongly affected by abstraction.

20. Setting levels of habitat retention (or maintenance) is an exercise in risk management. If an instream value is very significant then the level of habitat protection ought to be high in order to manage the risk that a reduction in habitat might pose to the maintenance of that value. The Proposed NES on Ecological Flow and Water Levels (MFE 2008), suggests that minimum flows should be 90% of the MALF for rivers and streams with mean flows less than or equal to 5 $m^3$/s, and 80% of MALF for rivers with mean flows greater than 5 $m^3$/s.

21. The proposed default minimum flow (Rule 5.96(2)) and at least some of the specific sub-regional minimum flows proposed in the pCLWRP are considerably lower than those suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008) and likely to cause some detrimental effect on fish populations and the ecological health

of waterbodies. I support the Department of Conservation ("DoC") submission that the default minimum flow should be the same as that proposed in the NES (i.e. 90% of the naturalised MALF for rivers with mean flow less than or equal to 5 $m^3/s$ and 80% of the naturalised MALF for rivers with mean flow >5 $m^3/s$). The specific sub-regional minimum flows should also aim to meet this default limit, unless detailed studies demonstrate that key instream values are being supported by status quo flows.

22. The proposed allocation limits at some sites in the pCLWRP are also considerably higher than that suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008) and could reduce flow variability and result in prolonged periods of flat-lining at the minimum flow. I again support the DoC submission that the allocation limits should be similar to that proposed in the NES (i.e. 30% of the naturalised MALF for rivers with mean flow less than or equal to 5 $m^3/s$ and 50% of the naturalised MALF for rivers with mean flow >5 $m^3/s$).

23. The pCLWRP includes two tables (Table 1a and 1b) that provide some guidance on what the Canterbury Regional Council are treating as the outcomes, or freshwater objectives, for rivers, streams and lakes in different management units throughout Canterbury. These tables are very important components of the pCLWRP and in my opinion need to be applied as bottom lines, and substantially refined with specific management purposes or freshwater objectives defined for each river management unit (as proposed by Hayward et al. (2009)), more indicators included, more specific information on the measurement statistics used to determine if these objectives have been met, and the replacement of narrative objectives with specific numeric objectives. I am also unconvinced about the need for a ‘natural state’ management unit.

24. The numbers included in Tables 1a and 1b are described as ‘outcomes’ in the pCLWRP. However, I believe that they should be considered as ‘freshwater limits’, as defined in the NPS for Freshwater Management. These limits should be linked with the management

purposes (i.e. freshwater objectives) and critical values, as proposed by Hayward et al. (2009).

25. In general, I support the limits that were proposed by Hayward et al. (2009), although I have suggested some amendments based on recent studies and updated information. I have helped Fish and Game produce a revised and updated version of Table 1, which is included with Fish and Game's submission and attached to Assoc Prof. Death's evidence.

**AN OVERVIEW OF WATER QUALITY IN THE CANTERBURY REGION**

26. The key parameters used to assess water quality include water temperature, water clarity and the concentrations of dissolved oxygen, nutrients (nitrogen and phosphorus), faecal bacteria, suspended solids and other contaminants.

27. Sensitive aquatic organisms are unable to survive in waterways where water temperatures or suspended solids concentrations are too high, or where water clarity or dissolved oxygen concentrations are too low. High concentrations of nutrients can lead to algal and cyanobacterial blooms in rivers which are unsightly, affect water and habitat quality, change invertebrate communities and ecosystem processes, and in some cases can be toxic to dogs and other organisms. Some nutrients (e.g. nitrate and ammonia) are also directly toxic to aquatic organisms at high concentrations. Swimming and other recreational values can be affected by poor water clarity and swimmers risk sickness if they swim in waterways with high concentrations of faecal bacteria. Waters with high concentrations of faecal bacteria are also unsuitable for human consumption or stock water drinking supplies.

28. Therefore, water quality limits are required to help maintain the life supporting capacity and values that are supported by waterways.

29. A report by Stevenson et al. (2010) provides a good overview of the water quality throughout the Canterbury region, although it is based only on data collected up to 2008. Ms Stevenson and colleagues summarised the data according to the management units that have

been proposed for the rivers of the Canterbury region by Hayward et al. (2009). These management units are: natural state, alpine-upland, alpine-lower, lake fed, hill fed-upland, hill fed-lower, Banks Peninsula, spring fed-upland, spring fed-lower basins, spring fed-plains, spring fed-plains-urban. Table 1a of the pCLWRP also uses these management units.

30. The values and management purposes within each of these management units have been described at a high level by Hayward et al. (2009). The identification of freshwater objectives (termed management purposes) as proposed by Hayward enabled limits to be established which provided for the identified freshwater values of waterbodies. I support this approach. This approach of identifying management purposes was also adopted in the NRRP, although I note that the numbers inserted into Table WQL5 of the NRRP are not limits in the context of the NPS Freshwater Management, but are attainable standards. The numbers in Table WQL5 were amended from those recommended by Hayward and therefore describe an environmental state somewhere between current state and a state that would provide for the environmental outcomes.

31. The pCLWRP has omitted to include management purposes or objectives for waterbody management units. Without identification of the values supported by particular waterbodies, freshwater limits cannot be set. However, ideally a more thorough approach to identification of values within specific water bodies should be conducted. This is done in Schedule XX of the Fish and Game submission for values relevant to Fish and Game's interests.

32. Water quality is very good in rivers and streams draining natural state and alpine areas, which reflects the low intensity of land development in these areas (Figures 1-3). All measures of water quality generally meet water quality standards set to protect sensitive aquatic life. However, there are indications of downstream increases in the concentrations of suspended solids, nitrogen, phosphorus and faecal indicator bacteria in the lower reaches of the large alpine rivers (alpine-lower class – Figures 1-3) such as the Hurunui, Waimakariri,

Rangitata, Rakaia and Waiau, which is a signal of inputs from developed land in the lower reaches of these systems.

33. Water quality of lake-fed and hill-fed rivers and streams is also generally good with cool water temperatures, adequate dissolved oxygen, and low concentrations of suspended solids and faecal indicator bacteria (Figures 1-3). The upland reaches of hill-fed rivers have relatively low concentrations of nutrients, while the lower reaches have higher concentrations of dissolved nitrogen and phosphorus with some sites indicative of 'enriched' conditions (Figure 1-3).

34. Streams draining Banks Peninsula have reasonable water quality, but concentrations of suspended solids are somewhat elevated and concentrations of dissolved phosphorus are high and often indicative of enriched conditions (Figures 1-3). This relates to the erodible loess soils and phosphate-rich volcanic geology that is distinctive of Banks Peninsula. Concentrations of faecal indicator bacteria in Banks Peninsula streams are also high (Figure 3); indicating that land use and stock access to waterways is also an issue in this part of the region.

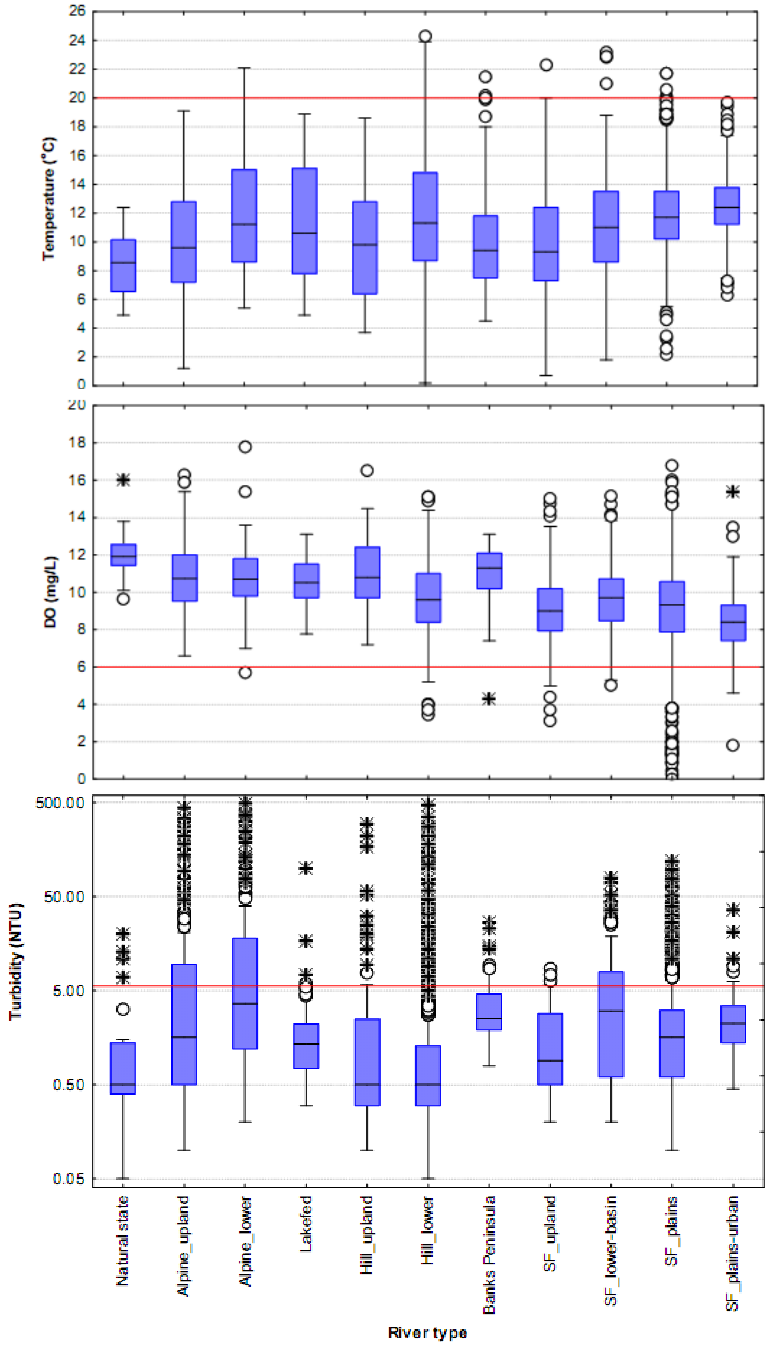


**Figure 1.** Distribution of spot temperature, dissolved oxygen and turbidity measurements for Canterbury river types. Appropriate guidelines are shown with the red lines. Modified from Stevenson et al. (2010).

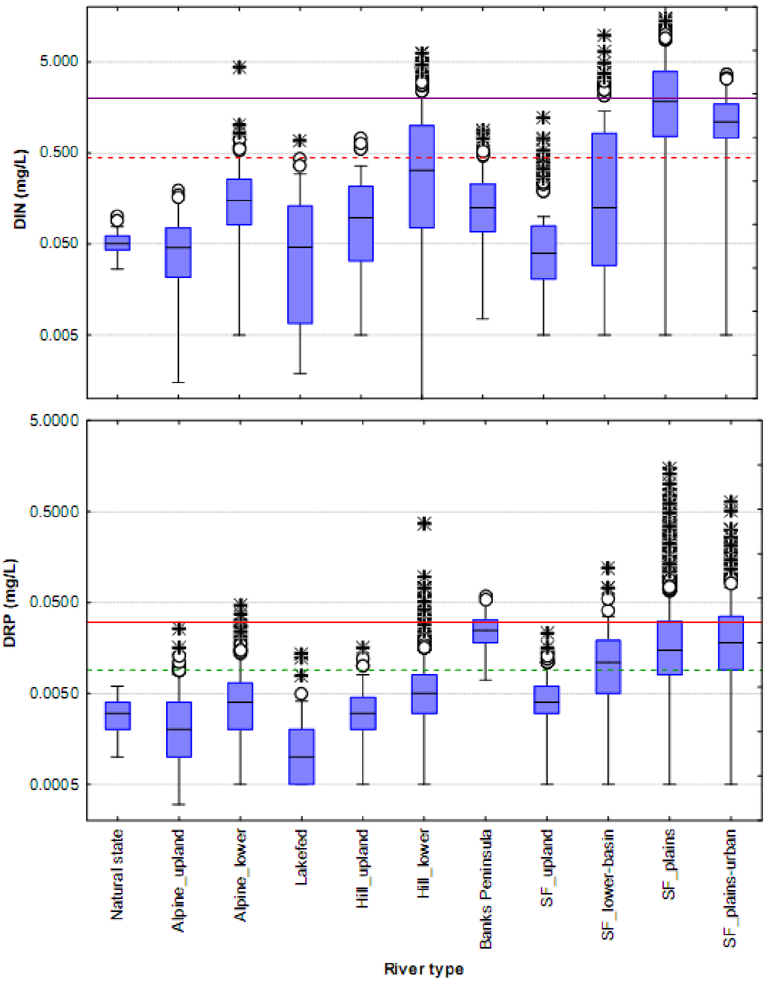


**Figure 2.** Distribution of dissolved inorganic nitrogen ("DIN") and dissolved reactive phosphorus ("DRP") measurements for Canterbury river types. Values above the dotted lines are indicative of enriched conditions, while values above the solid (purple and red) lines are evidence of excessive enrichment. Modified from Stevenson et al. (2010).

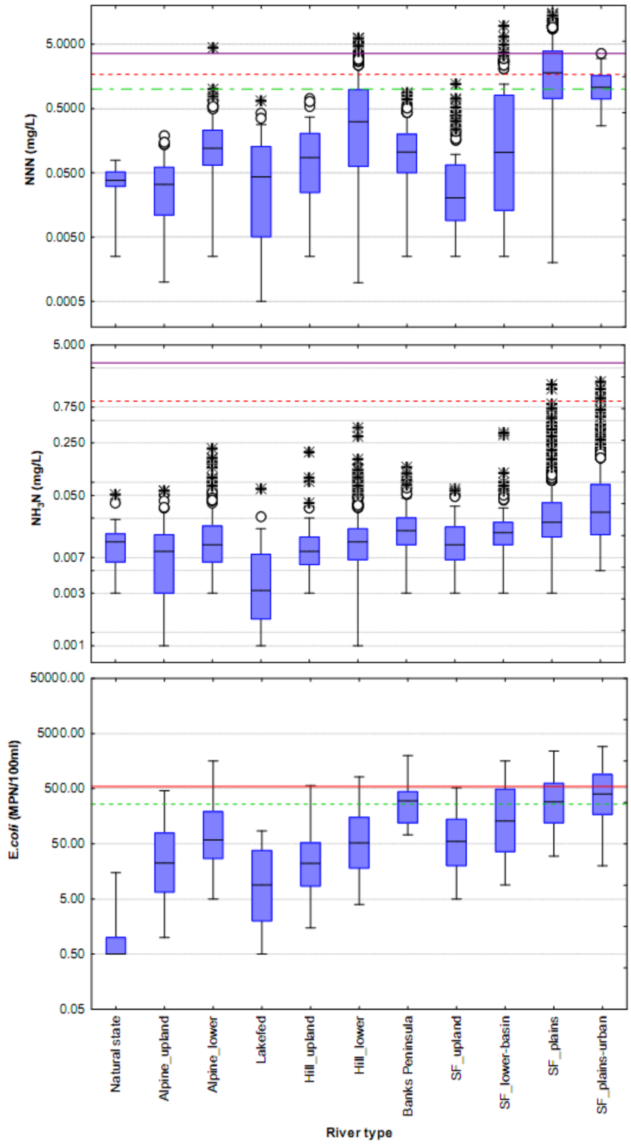


**Figure 3.** Distribution of nitrate/nitrite nitrogen ("NNN"), ammoniacal nitrogen ($NH_3$-N) and faecal indicator bacteria (*E. coli*) measurements for Canterbury river types. For the nitrate/nitrite graph, the green dot-dash line = 99% protection level; red dashed line = 95% protection level; solid purple line = 80% protection level for nitrate toxicity from Hickey & Martin (2009). For the ammoniacal nitrogen graph, the red dashed line = 0.9 mg/L (ANZECC chronic trigger value at pH 8); purple line = 2.9 mg/L (USEPA acute criteria at pH 8 and temp 25°C). For the E. coli graph the green dotted line is the alert guideline and the solid red line is the action guideline (MfE/MOH 2003). Modified from Stevenson et al. (2010).

35. Streams draining lowland parts of Canterbury are typically spring-fed and reliant on inputs of groundwater to maintain flows. Water temperatures are generally relatively cool in these systems (Figure 1), presumably due to the moderating influence of the groundwater inputs. However, most other water quality parameters indicate poor water quality in these systems. Dissolved oxygen levels are often relatively low and concentrations of dissolved phosphorus and particularly nitrogen are high and representative of 'enriched' or 'excessive' systems (Figures 1 and 2). Concentrations of faecal indicator bacteria are also high and these systems are regularly unsuitable for contact recreation (Figure 3).

36. Data from urban spring-fed streams on the plains was also poor and similar to water quality of spring-fed streams draining other lowland parts of Canterbury (Figures 1-3). The only possible exceptions were dissolved oxygen levels and faecal indicator bacteria concentrations which are somewhat worse (i.e. lower and higher, respectively) than for other spring-fed lowland streams in Canterbury (Figure 1 and 3).

37. A report by Meredith & Wilks (2007) provides a useful summary of the state of Canterbury's lakes. High country lakes in Canterbury generally have good water quality with low concentrations of nutrients and phytoplankton. Lakes Emma, Clearwater and Georgina are exceptions with some records indicating more enriched conditions, especially in dry years.

38. In contrast, lowland lakes in Canterbury, such as Ellesmere/Te Waihora and Forsyth/Te Roto o Wairewa, suffer from high concentrations of nutrients, phytoplankton and suspended solids. Lake Forsyth/Te Roto o Wairewa experiences toxic cyanobacterial blooms in most summers that endanger aquatic life, stock, dogs and potentially people that wish to recreate on or near the lake. Warning signs are erected at the lake advising people to avoid contact with the lake during blooms.

39. The suitability of rivers and lakes for swimming and boating is primarily assessed on the risk of infection from microbial pathogens, which is

measured using the concentrations of faecal indicator bacteria, and also the risk of cyanobacterial blooms. At the time of writing this evidence, 22 of the 62 freshwater recreational monitoring sites where data is available were classified as being of good or very good status on the Environment Canterbury website. Eighteen sites were classified as having fair status, while 4 and 18 sites were classified as having poor or very poor status, respectively. These latter sites included the Waihao, Waihi, Ashburton, Selwyn, Avon, Heathcote, Waimakariri, Kaiapoi and Ashley rivers, and Lakes Aviemore and Benmore.

40. Overall, the poor state of Canterbury's lowland rivers and lakes is a serious concern. Ecosystem health in many of these systems is degraded and needs severe and urgent attention if it is to be improved.

**TRENDS IN WATER QUALITY IN FRESH WATER BODIES IN CANTERBURY**

41. The report by Stevenson et al. (2010) also includes an analysis of trends in water quality parameters using data collected quarterly up to 2008. Some statistically significant and meaningful trends were detected with deteriorations and improvements in water quality recorded. Of note were the decreasing concentrations of nitrate nitrogen at 5 spring-fed urban streams near Christchurch, which Stevenson et al. (2010) attribute to improvements in industrial waste disposal which appear to have lowered nitrogen concentrations in the shallow aquifer. The substantial increase in nitrate concentrations in the lower reaches of many of the hill-fed rivers was also notable and is consistent with intensification of land use in these areas over the last decade.

42. It is, however, preferable to use data collected on a monthly basis for trend analyses because a higher sampling frequency provides more power for the statistical tests, thus increasing the ability to detect trends and reducing the influence of any outliers in the data that may skew the results. A recent report on the development of a standardised national monitoring and reporting programme has

recommended that monthly sampling be adopted as a standard in monitoring programmes throughout New Zealand (Davies-Colley et al. 2011).

43. In order to get an up-to-date picture of trends in water quality I conducted trend analyses on data collected from the 10 sites in the Canterbury region that are part of the NIWA National River Water Quality network (Table 1). Water quality has been measured monthly at these sites since January 1989, although faecal indicator bacteria have only been measured since February 2005. At the time of writing this evidence, the most recent data available for analysis was from September 2012.

44. Trend analyses were made using the non-parametric Seasonal Kendall test within the software package TimeTrends (v 3.0). This test takes into account the seasonal patterns in water quality that result from changes in runoff and instream uptake of nutrients throughout the year.

45. Six of the 10 sites had statistically significant increases in the concentrations of nitrate nitrogen over the last 24 years (Figure 4), while eight of the sites had a statistically significant increase in total nitrogen concentration over the same period (Table 1). The Waitaki at Kurow and Hakataramea at SH Bridge sites were the only sites where significant reductions in nitrate-nitrogen concentrations were observed (Figure 4), and no significant reductions were found for total nitrogen (Table 1).

46. Dissolved reactive phosphorus concentrations increased significantly only at the Opihi at Rockwood site, while total phosphorus concentrations increased at three sites and decreased at two sites.

47. Water clarity improved significantly at four of the ten sites (Table 1), while concentrations of faecal indicator bacteria (*E. coli*) increased at the Waimakariri at Gorge site and decreased at the Opihi at Rockwood site (Table 1).

48. The pattern of increasing concentrations of nitrogen that has been observed in these Canterbury rivers is also common in other rivers around the country. Statistically significant increases in total nitrogen were observed in 57 of the 77 National River Water Quality network sites over the period from 1989 to 2007, which is consistent with pastoral expansion and intensification throughout the country and the increasing use of nitrogenous fertilisers (Ballantine & Davies-Colley 2009). No statistically significant declines in total nitrogen concentrations were observed at any of the 77 sites over the same period.

**Table 1.** Results of trend analyses in key water quality parameters at the 10 National River Water Quality Network sites in Canterbury over the period from 1989 to 2012. Data for *E. coli* only cover the period from 2005 to 2012. Statistically significant declines in water quality are shaded in red and improvements are shaded in green. Ecologically significant trends (i.e. annual trend >1%) are shaded in darker colours. All data were flow adjusted before analysis.

| **Site** | **Clarity** | | **Diss. Phosphorus** | | **Nitrate N** | | **Total Nitrogen** | | **Total Phosphorus** | | **E. coli** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | p | RSKE% per year | p | RSKE% per year | p | RSKE% per year | p | RSKE% per year | p | RSKE% per year | p | RSKE% per year |
| Hurunui at Mandamus | NS | | NS | | NS | | <0.01 | 1 | NS | | NS | |
| Hurunui at SH1 Br. | NS | | 0.01 | 0 | <0.01 | 2.0 | <0.01 | 1.6 | <0.01 | 0.27 | NS | |
| Waimakariri at Gorge | NS | | 0.01 | 0 | <0.01 | 0.87 | <0.01 | 0.8 | NS | | 0.04 | 9.0 |
| Waimakariri above old HW Br. | NS | | NS | | <0.01 | 4.4 | <0.01 | 3.5 | NS | | NS | |
| Opihi at Grassy Banks | <0.01 | 0.9 | NS | | <0.01 | 2.2 | <0.01 | 1.8 | NS | | NS | |
| Opihi at Rockwood | NS | | <0.01 | 1.75 | <0.01 | 3.8 | <0.01 | 3.5 | 0.01 | 0.75 | <0.01 | -13 |
| Opuha at Skipton Br. | 0.01 | 4.9 | NS | | 0.04 | 0.99 | <0.01 | 1.6 | <0.01 | 2.6 | NS | |
| Waitaki at Kurow | <0.01 | 5.9 | NS | | <0.01 | -4.1 | NS | | <0.01 | -1.4 | NS | |
| Hakatakamea above MH Br. | NS | | NS | | 0.01 | -3.3 | <0.01 | 1.0 | NS | | NS | |
| Waitaki at SH1 Br. | <0.01 | 5.2 | NS | | NS | | NS | | 0.01 | -2.1 | NS | |

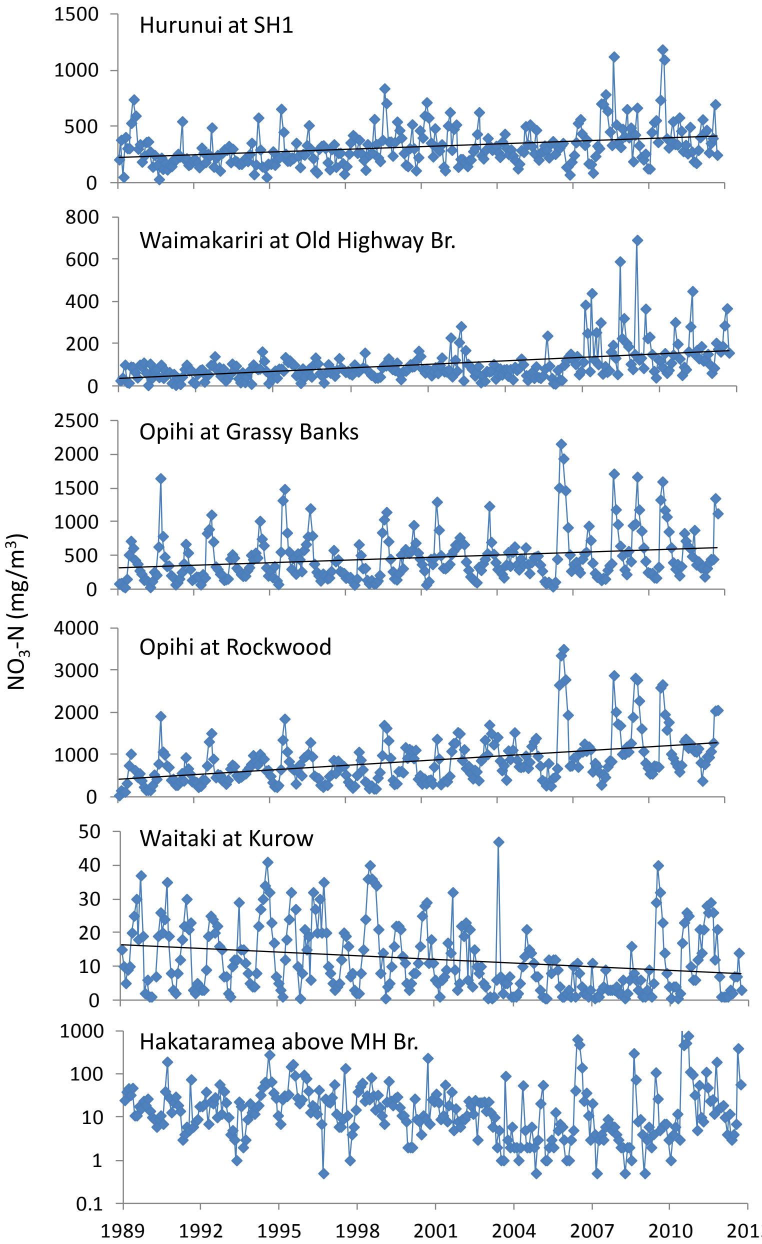


**Figure 4.** Trends in nitrate-nitrite nitrogen concentrations at 6 NIWA National River Water Quality Network sites in Canterbury. All trends are statistically significant and ecologically meaningful (i.e. RSKSE >1% per year). Note the differences in the scale of the y-axis on each graph.

**FACTORS AFFECTING WATER QUALITY IN FRESH WATER BODIES IN CANTERBURY**

49. The poor water quality in Canterbury's lowland rivers is primarily related to intensive land use in these areas. Similarly, the increasing concentrations of nitrogen that have been observed are consistent with the increasing intensity of land use in these areas.

50. This issue is not restricted to Canterbury and similar patterns of poor water quality in rivers draining intensive agricultural land are regularly reported throughout New Zealand (e.g. Parkyn & Wilcock 2004; Ballantine et al. (2010)). Removal of riparian vegetation, increased leaching and runoff of nutrients, sediment and faecal bacteria, and the bank erosion and direct faecal inputs that are associated with stock accessing waterways have resulted in declines in water quality and stream ecosystem health in many areas.

51. Water abstraction potentially also has effects on water quality, as it results in less water left in-stream to dilute contaminants in runoff. If abstracted for irrigation, any irrigation water passing the root zone and seeping back into the streams will likely be enriched with nutrients and faecal bacteria from the intensively irrigated land.

52. Storage of water in reservoirs can also affect water quality, particularly if water is held in the reservoir for a considerable period of time, and if the water in the reservoir becomes stratified with warm lighter water near the surface and cool, more dense water near the bottom (Young et al. (2004)). Surface waters in unshaded reservoirs can heat up substantially more than in partially shaded rivers, potentially affecting the thermal regime in downstream rivers receiving the reservoir water. Cooler waters in the bottom of a stratified reservoir can become anoxic, resulting in release of phosphorus, iron and manganese from the bed of the reservoir into the water column. Phosphorus can stimulate phytoplankton blooms in the reservoir and in downstream receiving waters, while iron and manganese can form unsightly flocs in downstream waters that potentially affect habitat quality.

**KEY HYDROLOGICAL FEATURES OF FLOW REGIMES FOR SUSTAINING RIVER ECOSYSTEMS AND INSTREAM VALUES**

53. The MfE Flow Guidelines for Instream Values (1998) state that there are two critical parameters of a flow regime that need to be prescribed for sustaining instream values that are dependent on proper functioning of river ecosystems. These are: 1) a minimum flow to fulfil water quality and habitat requirements, and 2) flow variability.

54. These guidelines are based on the concept of environmental flow regimes rather than just a minimum flow. Environmental flow regimes include the key minimum flow and flow variability features that maintain a river's physical and natural character, structure and function of its ecosystem and dependent values.

55. Minimum flows are usually required for maintaining instream habitat, but in some cases also for water quality.

56. Provision of flow variability at a variety of scales is required for maintenance of natural character, channel form, sediment and periphyton flushing, benthic invertebrate productivity, fish and bird feeding opportunities, and fishing opportunities.

57. Mechanisms for prescribing flow regimes to maintain the features that I have just described include:
    a. annual or seasonal minimum flows for maintaining instream habitat;
    b. allocation limits, or flow sharing rules, for maintaining flow variability and avoiding flat-lining of the minimum flows.

58. Key features of a flow regime and the effect of abstraction on these features are shown in Figures 5 and 6.

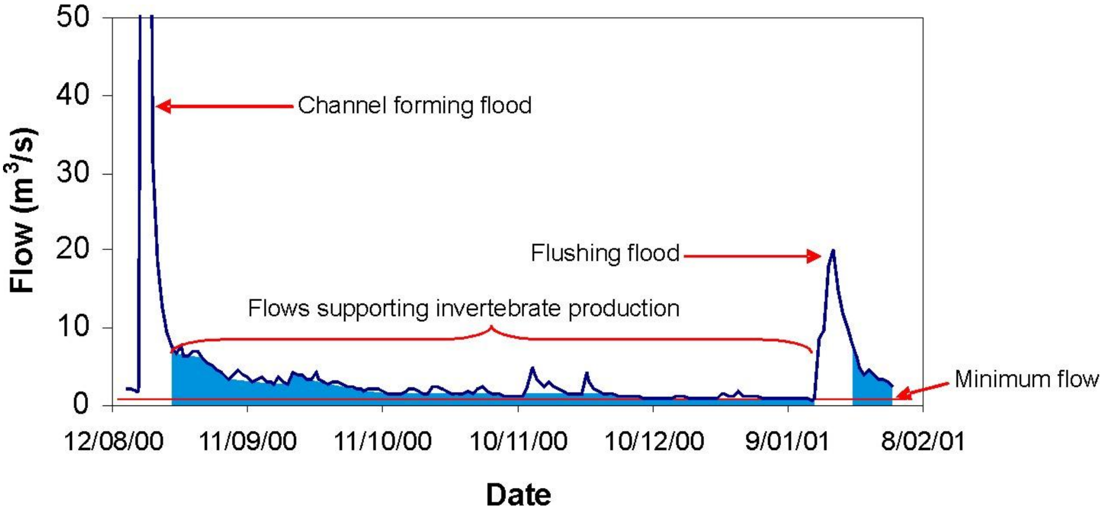


**Figure 5.** Illustrative hydrograph showing a minimum flow condition (1 $m^3/s$) and key variable flow features with their physical and ecological function. The blue-shaded area represents the part of the hydrograph that potentially provides habitat for algal and benthic invertebrate production (following flood disturbance and resetting of communities).

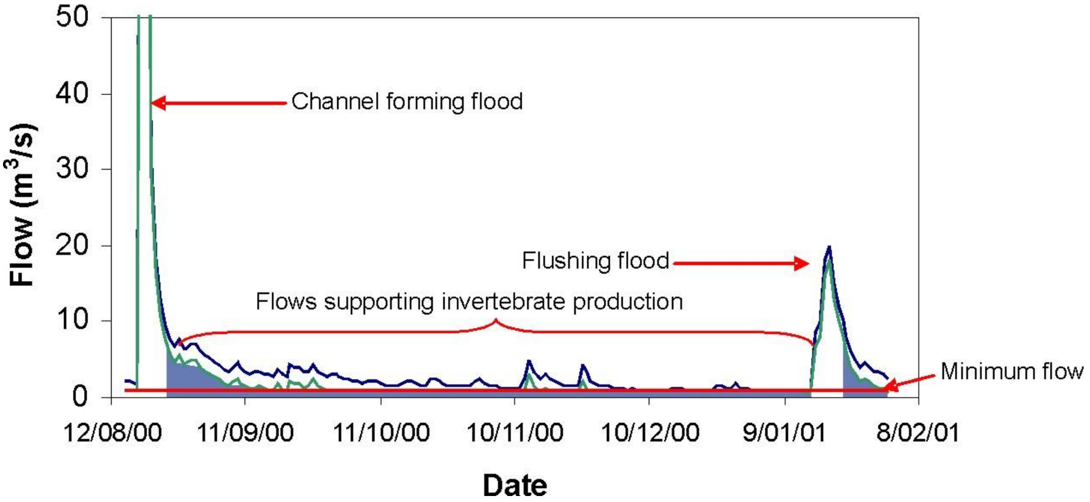


**Figure 6.** Illustrative hydrograph showing effect of run-of-river abstraction with relatively large allocation volume (2.6 x MALF) on key flow features. Natural flows are represented by the blue line and flows after abstraction by the green line. Allocation = 3 $m^3/s$, MALF = 0.774$m^3/s$, median flow = 2.04$m^3/s$). The blue-shaded area represents that part of the hydrograph that potentially provides habitat for algal and benthic invertebrate production (following flood disturbance and resetting of communities).

59. Breaches of an allocation limit increase the frequency of flat-lining at the minimum flow and affect surety of supply for consented users. Many flow assessments in the past have focused on the minimum flow, with either the MALF, or a proportion of it, set as the minimum flow condition. However, this practice assumes that appropriate flow allocation limits or flow sharing rules are set to largely maintain the natural flow variability and avoid prolonged periods of flat-lined flow. Referencing the minimum flow to the mean annual low flow, or less, in the absence of appropriate allocation limits or flow sharing rules has been likened to a doctor prescribing a patient's worst state of health as a life-time condition. There is a risk that water quality conditions may become marginal after prolonged periods at the minimum flow (e.g. high temperature and low dissolved oxygen levels), although the minimum flow ought to be set high enough to avoid this. Living space for fish is likely to be limiting at the minimum flow, and with fish concentrated in the remaining habitat, there will be increased competition and risk of predation – potentially resulting in lower growth and survival. Of course all of these potential effects will worsen if flow is drawn below the minimum, and will be exacerbated the longer low flows are sustained.

60. Abstraction above the minimum flow potentially reduces benthic invertebrate production. Flow recessions following floods wet a greater area than is wetted at the minimum flow. Periphyton and benthic invertebrates colonise such habitat after flood disturbance and contribute to annual production, with some of that production being cropped by fish and birds. The effect of run-of-river abstraction on flows that contribute to invertebrate production is illustrated in Figure 6. Flow recessions appear to enhance trout fishing opportunities in some rivers, with fish being more active and catchable than at low flow.

**SETTING AN ENVIRONMENTAL FLOW REGIME**

61. A basic principle established in the MfE Flow Guidelines is that instream values and their requirements be identified and appraised within the context of definite instream management objectives. Without these, instream values that are expressed in (non-monetary)

environmental or amenity terms may receive less consideration than out-of-stream uses of water, whose values can be expressed in terms of dollars. However, where objectives have been developed consultatively to reflect community aspirations, they can be accorded appropriate weight, even though they might not be expressed in monetary terms.

62. So the first step in environmental flow regime assessment is to identify significant instream values supported by the river, including ecological, recreational, and cultural values, then set management objectives to maintain them. In this case Fish and Game applied this step by identifying the instream values of relevance to its statutory functions in Schedule XX of its submission, and has adopted and amended Hayward's "Purposes for Management" as the objectives to protect, maintain and restore fishery and wildlife values.

63. The science of instream flow assessment has mainly focused on ecological values. These include indigenous fauna and flora (e.g. fish and birds), species supporting fisheries (e.g. native eels and galaxiids and introduced trout and salmon), and species underpinning life supporting capacity (e.g. algae and aquatic invertebrates). There is also some understanding of the flow needs of recreational values including fishing, boating and swimming, and of how the perception and realisation of Māori cultural values is influenced by flow and other environmental factors.

64. Of course, there are other values to consider when managing water allocation, namely the flow demands of out-of-stream uses such as irrigation, stock water, hydropower generation, and town supply. However, the environmental flow regime assessment component of water allocation is focused on providing sufficient quantity and pattern of flow to maintain instream values and life supporting capacity. Water can then be allocated for consumptive use above this limit.

65. The next step is to define goals and management objectives targeted at maintaining the significant values (Ministry for the Environment, 1998). As noted above, Fish and Game applied this step by adopting

Haywards "Purposes for Management" as objectives, and then setting limits and targets for water quality and quantity that would protect, maintain and restore the significant values identified in Schedule XX. Councils should do this in consultation with the public and institutional organisations. For assessing environmental flows it is helpful to identify the flow-dependent critical instream values and critical factors for sustaining these and the other values. Critical factors may include habitat availability, flow variability, water quality, and aquatic invertebrate food producing habitat – which itself has intrinsic life supporting capacity values.

66. A report by Jowett & Hayes (2004) for Environment Southland and the MfE defined critical values as follows: "The concept of critical values is that by providing sufficient flow to sustain the most flow-sensitive, important value (species, life stage, or recreational activity), the other significant values will also be sustained" (Jowett & Hayes (2004), p.8). The MFE Flow Guidelines recommend a similar approach, although the terminology used differs slightly. Basing decision-making on critical instream values circumvents the complexities of interpreting different habitat-flow relationships for a range of species and life-stages. I support this approach of identifying critical instream values and recommend that it should be adopted in the pCLWRP.

67. While the aim is to sustain the critical values and the full range of species, it is unrealistic to expect that all values will be maintained at original levels when flows change.

**ECOLOGICALLY RELEVANT FLOW STATISTICS**

68. Ecological flow assessments usually include modelling of instream habitat. These models predict how various habitat indices vary with flow. When setting minimum flows and allocation on the basis of instream habitat modelling predictions (and other methods), the assumption is made that there is a relationship between habitat change and population change. For this to occur, habitat or food needs to be limiting. However, usually there is insufficient information to determine whether habitat is limiting in Assessments of Environmental Effects and water resource assessments undertaken

for regional plans. Even if it were shown that habitat was not limiting, one would need to quantify the relationship between habitat and instream value in order to know by how much habitat could be reduced before the value declined significantly. Therefore, in the absence of such information it is precautionary to assume habitat and food is limiting, and base flow decisions on risk assessment of the degree of habitat or flow reduction (for the fish or bird species or its food). Alternatively, the results can be expressed as the level of habitat, or flow, retained instream. I discuss this further in Section 9 of my evidence.

69. Research on New Zealand rivers has found relationships between flow-related habitat and trout and native fish abundance, when habitat indices are referenced to ecologically relevant flow statistics. This research underpins the now common practice of referencing the predictions of instream habitat to ecologically relevant flow statistics in environmental flow assessments. The practice shortcuts the need to analyse time series of habitat over varying flows. The concept can be broadened to environmentally relevant flow statistics for angling and potentially for other forms of recreation and Māori cultural values.

70. The MALF is ecologically relevant to trout carrying capacity (Jowett (1992)) because it is indicative of the average annual minimum living space for adult trout and probably other annual spawning fishes. Mr Jowett found that trout abundance in New Zealand rivers was correlated with the quality of adult trout habitat (indexed by adult trout Habitat Suitability Index ("HSI")) at the MALF. He also found that the quality of benthic invertebrate habitat (indexed by “food producing” HSI) at the median flow, was strongly correlated with trout abundance. The correlation was even stronger with aquatic invertebrate biomass.

71. Aquatic invertebrates have much faster colonisation times than fish. For example, some taxa, such as the common mayfly *Deleatidium*, have multiple generations per year. Denuded habitat is quickly recolonised by invertebrates drifting from upstream refugia and by

winged adults laying eggs. Benthic invertebrate communities have been found to recolonise river braids within 30 days after drying.

72. Because of their rapid recolonisation times the median flow is an ecologically relevant flow statistic when assessing the effects of flow regime change on aquatic invertebrates.

73. The MALF is also relevant to native fish species, at least in small rivers where the amount of suitable habitat declines at flows less than MALF. Research in the Waipara River, where native fish habitat is limited at low flow, showed that the detrimental effect on fish numbers increased with the magnitude and duration of low flow (Jowett, Hayes & Duncan (2008)). Research on the Onekaka River in Golden Bay also showed that when habitat availability was reduced by flow reduction, abundance of native fish species responded in accord with predicted changes in habitat availability in both direction and magnitude (Jowett, Hayes & Duncan (2008)).

74. The amount of fish habitat at the MALF, and benthic invertebrate habitat at the median flow, are surrogate metrics of space and food, which are considered to be primary factors regulating stream fish populations. This rationale underpins the common practice of referencing minimum flow decisions on New Zealand rivers to fish habitat available at the MALF, and benthic invertebrate habitat to the median flow.

75. Provision for seasonal flow variation may also be sensible, to allow for seasonally varying food requirements of fish and birds and nesting requirements of the latter. Fish have higher food requirements in summer because their metabolic and consumption rates are higher at warmer water temperatures. Average summer minimum flows (usually summarised by the MALF) ought to be relevant to minimum space requirements for fish, while median summer flows ought to be relevant to maintenance of fish feeding opportunities and fish production. In some cases higher winter flows may be prescribed for trout spawning

habitat, although water demand is often lower in winter – at least for irrigation.

76. Similarly, referencing benthic invertebrate habitat to the summer median flow, or even to monthly median flows, may be appropriate given the rapid recolonisation times of invertebrates.

77. A flow of three times the median flow is generally considered to the large enough to effectively flush periphyton and deposited detritus from the river bed in most situations (Clausen & Biggs (1997)). Therefore, maintenance of the frequency of flows of this size (FRE3) should be an important objective in water management.

78. Maintenance of the frequency of larger floods responsible for forming and maintaining the river channel is also important.

79. In Canterbury rivers, maintaining the frequency of flows that are sufficient to open the river mouths is also an important consideration.

80. When assessing and setting an environmental flow regime, the flow statistics on which they are based ought to be naturalised (i.e. the natural MALF), rather than based on measured river flows, which may be strongly affected by abstraction. Calculation of the natural MALF is relatively easy if there are good records of river flow and abstraction and a good understanding of natural losses of surface flow to groundwater. However, in many cases information on actual rates of abstraction is very poor and understanding of the role of abstraction on surface water-groundwater interactions is often very limited.

**LEVELS OF HABITAT MAINTENANCE**

81. The next step in laying the foundation for environmental flow assessment is deciding on the levels at which instream values should be maintained. These levels are referenced to the habitat sustained at the ecologically relevant flows. MfE's Flow Guidelines for instream values suggest that the level of maintenance should reflect the merits of instream values in a particular river (e.g. the quality and use of a

recreational fishery, the biological diversity of a stream ecosystem, the conservation status of river bird population, the availability of alternatives, or means of mitigation). The concept of retaining a percentage of the "natural" condition is one means of defining the level of maintenance, with the proportion of habitat retained varying according to the merits of the instream values and community aspirations.

82. Setting levels of habitat retention (or maintenance), boils down to a weighing up of values and risks. If an instream value is very significant then the level of habitat protection ought to be high in order to manage the risk that a reduction in habitat might pose to the maintenance of that value.

83. In their report to Environment Southland, Jowett & Hayes (2004) suggested that water managers could consider varying the percentage habitat retention level, depending on the value of instream and out-of-stream resources within the ranges presented in Table 2. A high quality fishery of national significance, or a threatened species of national or international conservation status, might warrant at least a 90% habitat retention level. A low valued fishery of local significance might warrant up to 70% habitat retention, and a moderately valued fishery – say of regional significance – would fall somewhere in between these levels of habitat retention. Species with intrinsic value but no special conservation significance might rank as low value, perhaps warranting at least 60% habitat retention with the implicit understanding that the resultant habitat loss (40%) runs a high risk of reducing life supporting capacity. This might be acceptable for widespread species with only intrinsic value. Note though that for these species ecosystem functioning should also be taken into consideration when ascribing value and significance. For instance, native fish, such as bullies, with no direct fishery value, and benthic invertebrates, are prey for fish with fisheries value (such as trout and eels) and for birds, some of which have threatened conservation status (e.g. black-fronted terns and wrybills).

**Table 2.** Suggested significance ranking (from highest (1) to lowest (5)) of critical values and levels of habitat retention for selected values. From Jowett & Hayes (2004).

| **Critical value** | **Fishery quality** | **Significance ranking** | **% habitat retention** |
|---|---|---|---|
| Large adult trout – perennial fishery | High | 1 | 90 |
| Diadromous galaxiid | High | 1 | 90 |
| Non-diadromous galaxiid | - | 2 | 80 |
| Trout spawning/juvenile rearing | High | 3 | 70 |
| Large adult trout – perennial fishery | Low | 3 | 70 |
| Diadromous galaxiid | Low | 3 | 70 |
| Trout spawning/juvenile rearing | Low | 5 | 60 |
| Bullies e.g. upland, common, bluegill | - | 5 | 60 |

84. In my opinion the suggested levels of habitat retention in Table 2 are conservative, in that they are unlikely to be directly proportional to a population response. Theoretically, a change in available habitat will only result in a population change when all available habitat is in use (i.e. the population is at carrying capacity). In most rivers, because flows are varying all the time, population densities probably are at less than maximum levels. That being the case, and speaking very broadly, a habitat retention level of, say 90%, should maintain existing population levels, whereas a habitat retention level of 50% probably will result in some detrimental effect on populations, especially where densities are high.

**ENVIRONMENTAL FLOW REGIMES IN THE PROPOSED CANTERBURY LAND AND WATER PLAN**

85. In my opinion, the Proposed Canterbury Land and Water Plan is light on detail regarding water allocation and ensuring that environmental flow regimes are suitable throughout the Canterbury region. For example, the objectives are at a very high level and there is no specific mention of a need to maintain river flows or flow variability at a certain level to maintain ecosystem health in surface waterbodies.

This contrasts markedly from the proposed Hurunui/Waiau Regional Plan, which was quite specific about these objectives.

86. I support Policy 4.50, which notes that abstraction requires an instantaneous allocation limit, a minimum flow and cessation of abstraction may be required to maintain flow variability.

87. However, I note that in Rule 5.96(2) of the original pCLWRP "if no limits are set in Sections 6-15 for that surface water body, the take, both singularly and in addition to all existing resource consented takes meets a flow regime with a minimum flow of 50% of the 7-day mean annual low flow (7DMALF) as calculated by the CRC and an allocation limit of 20% of the 7DMALF."

88. This 'default' position for the minimum flow is considerably different from the interim limits in the Proposed NES on Ecological Flow and Water Levels (MFE 2008), which suggests that minimum flows should be 90% of the MALF for rivers and streams with mean flows less than or equal to 5 $m^3/s$, and 80% of MALF for rivers with mean flows greater than 5 $m^3/s$. I understand that the Department of Conservation submission seeks to import the NES interim limits into rule 5.96, which is supported by Fish and Game. In my opinion this is appropriate. By comparison the default position in the plan as notified is also considerably lower than that suggested in Table 2 above and would be expected to result in some detrimental effects on fish and invertebrate populations.

89. I have not be able to locate information on naturalised 7D MALFs at all the sites where specific environmental flow and allocation limits are proposed in the sub-regional sections of the proposed CLWRP. However, at sites in the Ashburton Catchment where this information is available it appears that the minimum flows proposed range from <20% (Pudding Hill) to 67% (South Ashburton) of the natural 7DMALF's (Table 3). The initial proposed minimum flow for the Ashburton River at SH1 (6 $m^3/s$) is 44% of the naturalised 7DMALF, but the proposed plan includes a provision to raise this to 10 $m^3/s$

(74% of 7DMALF) from August 2022. All of these proposed minimum flows are lower than those suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008).

**Table 3.** Comparison of minimum flow and allocation limit with naturalised 7-day mean annual low flow (7DMALF) at four sites in the Ashburton Catchment.

| Site | Naturalised 7DMALF ($m^3/s$) | Minimum Flow (A-allocation) ($m^3/s$) | A-allocation ($m^3/s$) | B-allocation ($m^3/s$) | Minimum flow as a percentage of 7DMALF | A-allocation as a percentage of 7DMALF |
|---|---|---|---|---|---|---|
| Ashburton at SH1 | 13.46 | 6.0[1] | 0.253 | 0.5 | 44.6 | 1.9 |
| Sth. Ashburton at Mt Somers | 4.735 | 2.3[2] | 5.1 | 2.0 | 48.6 | 107.7 |
| Pudding Hill | 0.47 | 0.08 | 0.528 | | 16.9 | 111.4 |
| Taylors | 0.87 | 0.5 | 4.465 | 0.2 | 57.7 | 515.0 |

[1]the pCLWRP proposes that the minimum flow in the Ashburton River at SH1 shall be 10.0 $m^3/s$ from August 2022.
[2]the summer (October to April) minimum flow proposed in the pCLWRP is 3.2 $m^3/s$

90. Default allocation limits in the Proposed NES on Ecological Flow and Water Levels (MFE 2008) were the greater of 30% of MALF or the total allocation from the catchment on the date of implementation of the NES for rivers and streams with mean flows less than or equal to 5 $m^3/s$; and the greater of 50% of MALF or the total allocation from the catchment on the date of implementation of the NES for rivers with mean flows greater than 5 $m^3/s$.

91. Allocation limits proposed in the CLWRP for at least some sub-regions are split into A-block, B-block and C-block allocations (e.g. Section 8, Ashley allocation limits), with decreasing reliability of supply going from A-block to C-block. In the Ashburton Catchment where information on 7DMALF's are available, A-block allocations range from 2% (Ashburton at SH1) to >500% (Taylors Stream) of the naturalised 7DMALF (Table 3). A-block allocations from the South Ashburton and Pudding Hill are also above 100% of MALF (Table 3). B-block allocations are on top of this. The proposed allocation limits at some sites are therefore considerably higher than that suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008) and could reduce flow variability and result in prolonged periods of flat-lining at the minimum flow and adverse effects on ecosystem health and life supporting capacity.

**LIMITS/OBJECTIVES FOR PROTECTING INSTREAM VALUES**

92. The proposed CLWRP includes two tables (Table 1a and 1b) that provide some guidance on what the Canterbury Regional Council are treating as the outcomes, or freshwater objectives, for rivers, streams and lakes in different management units throughout Canterbury.

93. These tables are very important components of the pCLWRP and in my opinion need to be applied as bottom lines, and substantially refined with specific management purposes or freshwater objectives defined for each river management unit (as proposed by Hayward et al. (2009)), more indicators included, more specific information on the measurement statistics used to determine if these objectives have been met, and the replacement of narrative objectives with specific

numeric objectives. I am also unconvinced about the need for a 'natural state' management unit.

94. The numbers included in Tables 1a and 1b are described as 'outcomes' in the pCLWRP. However, I believe that they should be considered as 'freshwater limits', as defined in the NPS for Freshwater Management. These limits should be linked with the management purposes (i.e. freshwater objectives) and critical values, as proposed by Hayward et al. (2009).

95. Hayward et al (2009) reviewed the proposed NRRP water quality objectives and standards for river and lakes in Canterbury. This report is a thorough and well considered discussion of potential objectives that could be applied in the different management units throughout Canterbury.

96. Hayward et al. (2009) questioned the relevance of the 'natural state' river management unit that was used in the current Natural Resources Regional Plan and is also included in the pCLWRP. I also consider that the 'natural state' river management unit is potentially redundant. All of the rivers and streams represented by this management unit could be equally well represented by one or other of the alpine-upland, hill fed-upland or spring fed-upland classes. The main benefit of deleting the natural state management unit would be that the loose narrative objective "rivers are maintained in a natural state" that is in the pCLWRP could be replaced by more specific numeric objectives making it feasible to determine if the objective has been met or not.

97. Objectives for ecological health for each river management unit were also suggested by Hayward et al. (2009), which Fish and Game propose be applied as limits in Table 1a. One measure of the ecological health of rivers is the Quantitative Macroinvertebrate Community Index ("QMCI"). Values less than 4 are indicative of degraded systems. I note that the QMCI values in Table 1a in the pCLWRP tend to be lower than those recommended by Hayward et al. (2009) and include a range (e.g. Alpine-lower 5-6). It doesn't make sense to me to have a range of values as a limit for QMCI and there is

no information on how compliance with these limits will be measured. I suggest that the single values proposed by Hayward et al. (2009) and used in Fish and Game's revised version of Table 1a are used in the CLWRP and that a three year rolling mean of annual measurements is used to determine if the QMCI objective is being met. The three-year rolling mean, rather than one-off measurements, will help smooth out natural variability in QMCI measures.

98. A similar concern with compliance relates to the dissolved oxygen limit. Dissolved oxygen concentrations can vary widely over a 24 hour period because aquatic plant photosynthesis (and oxygen release) tends to increase dissolved oxygen levels during the day and then respiration (and oxygen consumption) of all aquatic life decreases dissolved oxygen levels at night (Figure 7). Minimum dissolved oxygen concentrations are typically observed at dawn and are usually missed in one-off spot measurements. Many regional councils are moving towards monitoring programmes that include continuous dissolved oxygen measurements so this problem can be avoided.

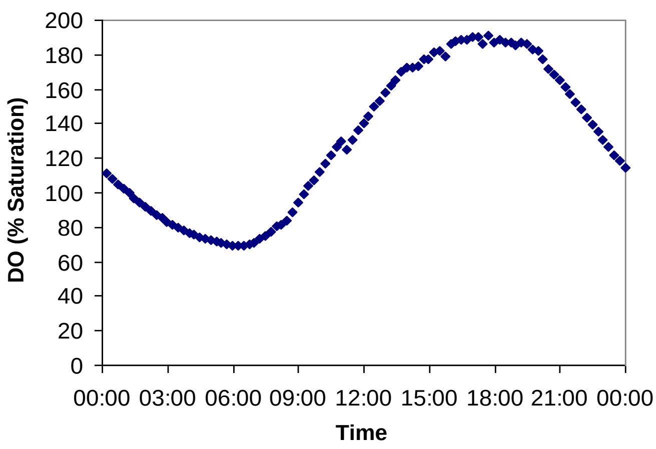


**Figure 7.** Example of a 24 hour variation in dissolved oxygen saturation in a river.

99. For dissolved oxygen I recommend that the limits should relate to daily minimum values. For example, I recommend something like the following "The 5$^{th}$ percentile of daily minimum dissolved oxygen measurements in the XXXX river management unit shall not fall below XX% saturation."

100. The concentrations of dissolved oxygen in the water are a critical component affecting the life supporting capacity of a river system. The ANZECC (1992) guideline of 80% minimum dissolved oxygen saturation is potentially appropriate for all river management units, but a higher guideline for some river management units, as suggested by Hayward et al. (2009) and proposed in Fish and Game's submission is also potentially suitable.

101. A similar situation exists for water temperature with large daily fluctuations occurring at some sites and maximum temperatures normally occurring in mid-afternoon. Spot measurements again often miss the critical maximum daily water temperatures. For the temperature limit I recommend something like "The 95$^{th}$ percentile of daily maximum water temperature measurements in the XXXX river management unit shall not exceed XX°C."

102. Trout and salmon will cease feeding once water temperatures exceed 19°C, and they will begin to die once temperatures climb above 25°C for a sustained period. Juvenile eels will also die once temperatures reach the mid 20's. I recommend that the water temperature limit for the upland river management units is 19°C, which corresponds with the recommendation from Hayward et al. (2009) and the Fish and Game submission. The lack of shading and open-braided nature of many Canterbury rivers make the smaller rivers particularly susceptible to high summer temperatures, making a higher objective, such as, more appropriate in these river management units. Hence, the 20°C limit proposed for these river management units in the Fish and Game submission.

103. Winter water temperatures are also important in relation to incubation of trout and salmon eggs. Jowett (1992) found that rivers with winter water temperatures >10°C contained very few, or no, brown trout. Therefore, I support the inclusion of an additional temperature limit over the trout/salmon spawning and egg incubation period (May to September), which is included in Fish and Game's revised Table 1a.

104. I note that limits relating to water clarity, toxicants and nutrients that were recommended by Hayward et al. (2009) do not appear in Table 1a of the pCLWRP. This is a serious omission since it will be impossible to manage the use and development of land and of contaminant discharges if it is not clear what the objectives are. Nutrient and some toxicant limits (and a clarity change limit) are proposed as standards in Schedule 5 of the pCLWRP, but these appear to be primarily aimed at controlling individual point source discharges and thus not able to be used to control cumulative effects of non-point source discharges. Fish and Game's submission seeks that limits relating to these key water quality parameters are included in the CLWRP (their revised Table 1a). I also consider that these are important indicators of whether outcomes/objectives for Canterbury rivers will be met and agree that they should be included in the plan.

105. Rules 5.39 – 5.51 in the pCLWRP appear to be the main method suggested for maintaining and improving water quality in the Canterbury region, but these rules are not related to instream concentrations of nutrients, periphyton levels, water clarity or deposited sediment levels. In my opinion a much better approach is to set instream limits (e.g. for periphyton cover) and a management regime that will ensure water quality moves towards meeting the instream limits within a reasonable timeframe.

106. The periphyton chlorophyll *a* biomass and filamentous algae cover limits in the pCLWRP are directly from Hayward et al. (2009). In his evidence Assoc. Prof. Death shows the lack of correspondence between the algal chlorophyll *a* biomass objectives and the algal cover objectives (i.e. 200mg/m$^2$ is generally >30% cover). I support the filamentous algae cover limits outlined in Hayward et al. (2009) but following Assoc. Prof. Death suggest that 120mg/m$^2$ is the highest chlorophyll *a* limit, as proposed in Fish and Game's submission.

107. I note that a recent review of NZ instream plant and nutrient guidelines (Matheson et al. (2012)) also suggests a focus on periphyton cover (with a guideline at 30% cover) and less reliance on chlorophyll *a* biomass measurements.

108. As is the case for all of these proposed limits the statistic that should be used to determine compliance with the periphyton limits is not defined in the pCLWRP. I recommend something like the following "The 95th percentile of monthly periphyton biomass measurements in the XXXX river management unit does not exceed XXXmg/m$^2$ or XX% cover of filamentous algae." This wording defines how often periphyton should be measured, the statistic that should be used to determine compliance, and still allows occasional exceedance of the objective, as may occur during unusually long periods of stable low flow.

109. Once periphyton objectives are set for each river management unit, it is then possible to consider what nutrient concentration limits should be set in the CLWRP. As mentioned earlier, there are no nutrient concentration limits included in the pCLWRP. Hayward et al. (2009) considered appropriate nutrient concentration objectives and standards for each of the river management units and I support those recommendations. Hence, the figures in the Fish and Game evidence are directly from Hayward et al. (2009).

110. Controls on both nitrogen and phosphorus concentrations should be adopted in the CLWRP because it can be difficult to predict if one particular nutrient is limiting (Keck & Lepori (2012)) and there are risks involved with managing a single nutrient and relaxing controls on the other nutrient (Wilcock et al. (2007); Larned et al. (2011)).

111. Hayward et al. (2009) recommended objectives for deposited fine sediment cover. Considerable additional research has been conducted since 2009 on guidelines for interpreting deposited sediment measurements (Clapcott et al. (2011)), which should be incorporated in the CLWRP. Ms Clapcott and colleagues' analyses suggest that fine sediment cover should be less than 20% (or within 10% cover of reference conditions) to maintain biodiversity and salmonid spawning habitat values, while fine sediment cover should be less than 25% to maintain amenity values.

112. These values are relatively consistent with those proposed by Hayward et al. (2009) for each of the river management units and I am therefore comfortable with the deposited sediment limits in the pCLWRP. Fish and Game's submission is largely based on the pCLWRP deposited sediment limits, but seeks that a 20% cover limit should also apply to urban spring-fed plains streams.

113. Hayward et al. (2009) also recommended water clarity objectives for each river management unit using information on the effects of water clarity on fish foraging and on existing data on water clarity in each river management unit. I am comfortable with the values recommended by Hayward et al. (2009) and consider that these should also be included in the CLWRP, as proposed in Fish and Game's submission.

114. Interim guidelines on cyanobacteria in recreational freshwaters are now available (MFE/MOH 2009) and should replace the narrative guideline in the pCLWRP. This MFE/MOH report recommends an 'alert' mode is adopted if benthic cyanobacteria cover is between 20-50%, and 'action' mode is adopted if >50% of the bed is covered in potentially toxic cyanobacteria, or if cover is <50% but potentially toxic cyanobacteria are visibly detaching from the substrate, accumulating as scums along the river's edge or becoming exposed on the river's edge as the river level drops. Therefore an appropriate limit for benthic cyanobacteria cover for all rivers is 20% cover with no potentially toxic cyanobacteria visibly detaching from the substrate, accumulating as scums along the river's edge or becoming exposed on the river's edge as the river level drops.

115. Similarly for management of toxic cyanobacteria in lakes, the MFE/MOH report recommends an 'alert' mode is adopted if a biovolume of potentially toxic planktonic cyanobacteria equivalent to 0.5 to $<1.8mm^3/L$ is present or if a total bio-volume of 0.5 to $< 10mm^3/L$ of all cyanobacterial material is present. This could be adopted as a numeric guideline for all lakes and replace the current narrative guidelines in the pCLWRP.

116. As I mentioned in an earlier section of my evidence, the proposed default minimum flow (Rule 5.96(2)) and at least some of the specific sub-regional minimum flows proposed in the pCLWRP are considerably lower than those suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008) and likely to cause some detrimental effect on populations, especially where densities are high. I support the DoC submission that the default minimum flow should be the same as that proposed in the NES (i.e. 90% of the naturalised MALF for rivers with mean flow less than or equal to $5m^3/s$ and 80% of the naturalised MALF for rivers with mean flow $>5m^3/s$). The specific sub-regional minimum flows should also aim to meet this default limit, unless detailed studies demonstrate that key instream values are being supported by status quo flows.

117. The proposed allocation limits at some sites are also considerably higher than that suggested in the proposed NES on Ecological Flows and Water Levels (MFE 2008) and could reduce flow variability and result in prolonged periods of flat-lining at the minimum flow. I again support the DoC submission that the allocation limits should be similar to that proposed in the NES (i.e. 30% of the naturalised MALF for rivers with mean flow less than or equal to $5m^3/s$ and 50% of the naturalised MALF for rivers with mean flow $>5m^3/s$).

**Roger Graeme Young**

**4 February 2013**

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