BEFORE THE INDEPENDENT COMMISSIONERS

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER	of the Proposed Variation 1 to the Proposed Canterbury Land and Water Regional Plan

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EVIDENCE IN CHIEF OF MR BRETT STANSFIELD ON BEHALF OF NORTH CANTERBURY FISH AND GAME COUNCIL AND THE ROYAL FOREST AND BIRD PROTECTION SOCIETY

September 2014

North Canterbury Fish and Game Council

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1. I am presently the Director and Principal Scientist of Environmental Impact Assessments Limited, a consultancy based in Auckland specialising in freshwater quality, aquatic macroinvertebrate taxonomy and ecology of rivers, lakes and wetlands of New Zealand.

2. I hold a BSc in Biology and postgraduate diploma in Zoology (Massey University) and a MSc (Hons) in freshwater ecology obtained from Auckland University in 1994

3. My additional tertiary education since this time has included the following courses:

   a. New Zealand's Natrual Heritage (Massey University 2002)

   b. Data Analysis (Massey 2003).

   c. Multivariate Statistical Methods (Massey 205).

   d. Forecasting and Time Series Regression (Massey 2006)

4. I have previously served as a freshwater scientist for two regional councils (Wellington Regional Council 1995 – 2000 and Hawke's Bay Regioinal Council 2000 – 2010). In these roles I provided expert advice to council in freshwater plan development, state of the environment monitoring for rivers, lakes and wetlands and setting of resource consent conditions pertaining to point source discharges.

5. In 2008, I began a part time consultancy in Napier and in 2010 resigned from council to pursue the business further.

6. I am an accredited provider of freshwater macroinvertebrate taxonomy and have recently begun teaching this skill to undergraduate students at Auckland University of Technology as a guest lecutrer.

7. Since 2009 I have been hosting one day training workshops for council scientific officers and cosultants on aspects of water quality, ecology and statistical analysis of data.

8. I am a professional member of the New Zealand Freshwater Sciences Society and the New Zealand Water and Wastes Association.

9. In preparing this evidence I have read and in some cases reviewed all literature cited at the end of this document.

Expert Witnesses Code of Conduct

10. 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

11. I have been asked by the North Canterbury Fish and Game Council and the Royal Forest and Bird Protection Society to prepare evidence in relation to variation 1 of the proposed Canterbury Land and Water Regional Plan. This includes:

    a. The ecological values of the Te Waihora / Lake Ellesmere Catchment.

    b. A summary of state and trends of water quality of the Te Waihora / Lake Ellesmere catchment

    c. A critique of the mitigation measures of the scenarios provided by the Zone Implementation Committee

    d. A critique of the modelling used to assist with decision making

    e. A critique of the water quality and flow conditions set in plan variation 1 along with proposed amendments to those conditions to ensure that the prime objectives of the Canterbury Water Management Strategy are met.

    f. Some comment on the importance of dual nutrient management for lakes and rivers to protect ecological health of these systems.

    g. A reference list of all literature cited.

EXECUTIVE SUMMARY

12. There is a considerable body of evidence that intensive agricultural land uses can have significant adverse effects on the ecological health of water bodies in New Zealand. The principal driving factors for these adverse effects include increased nutrient concentrations, loss of riparian habitats, altered and reduced flows and increased suspended and deposited sediment.

13. Since the second half of the 19th century, Te Waihora has been situated in a predominantly agricultural catchment. Agriculture has intensified since the late 1990s.

14. Lake Ellesmere / Te Waihora is the final aquatic receiving environment of the catchment before its waters discharge to sea. The lake has received a legacy of diffuse nutrient and sediment discharges from agriculatural intensification of the upstream catchment over a number of decades which has resulted in it becoming the most polluted lake in New Zealand.

15. In my view the lake cannot be restored to its former glory (mesotrophic lake with abundant aquatic macrophyte growth) however it can be rehabilitated to a less degraded state.

16. A key requirement for lake rehabilitation is a signficant reduction in total phosphorus and total nitrogen loads (TP and TN) to give rise to reduced concentrations of these nutrients.

17. Many of the mitigation strategies proposed for the various scenarios will not be effective unless greater management of TP and TN is demonstrated by the plan variation.

18. The overall objective of lowering the Trophic Level Index (TLI) of the lake is unlikely to occur unless there is complete success with all mitigation strategies of which the probability of success is unknown and entirely interdependent upon each other.

19. In my view, some of these mitigation strategies will not be effective owing to the current water quality and ecological status of the lake.

20. Modelling undertaken to determine ecological effects of the various scenarios is hindered by a large amount of error owing to error

contained in the model inputs and error in assessing the effectiveness of the mitigation strategies.

21. This evidence provides some critique on the existing water quantity, quality and ecological standards proposed in plan variation 1. In doing so I have provided some alternative threshold criteria to ensure that the ecosystem outcomes specified for the Selwyn Te Waihora Zone are met.

ECOLOGICAL VALUES OF THE TE WAIHORA / LAKE ELLESMERE CATCHMENT

22. Te Waihora is a RAMSAR wetland of international importance due to its large number of resident and migratory birds (166 species recorded) occupying its extensive, periodically inundated marginal and wadeable habitat. Te Waihora / Lake Ellesmere has amongst the most abundant bird densities of any lake in New Zealand (Norton et al 2014).

23. Te Waihora / Lake Ellesmere is a brackish lake that has occasional water exchanges with the coastal environment owing to the managed openings of the lake to prevent flooding of land and the entering of coastal water at high tides as lake water levels recede. These lake opening occurrences assist an important migratory pathway for diadromous fish during autumn and spring. Te Waihora / Lake Ellesmere forms an important component of the coastal marine environment during these water exchanges.

24. Sixty three vegetation types were identified surrounding the lake shore of Lake Ellesmere in 2007 (Grove & Pompei In Hughey & Taylor 2009).

25. The lake shore contains a unique mosaic of brackish and freshwater wetland environments that provide vegetation complexes unique to each habitat type.

26. The proportion of these habitat types has largely been driven by historical control of lake water levels.

27. There has been a discerning decline in native vegetation composition of the freshwater wetlands of Te Waihora. In 1983 native freshwater wetland vegetation covered 245 ha, 54% of the available habitat (452 ha). By 2007, native freshwater wetland vegetation cover was reduced to 197 ha, only 35% of a larger total area (555 ha).

28. Areas of exotic crack- and/ or grey willow- *(Salix fragilis and S. cinerea)* dominant forest and scrub vegetation has doubled, from 67 ha of the lakeshore survey area in 1983 to 140 ha in 2007.

29. Grove and Pompei (In Hughey & Taylor) stress the need to eradicate willow and shrub weed species in order to maintain the biodiversity of these important ecotones[1].

30. A total of 47 species of fish have been recorded in Te Waihora / Lake Ellesmere and its tributaries (Rennie & Lomax 2013). The lake forms an important conduit for recruitment of diadromous fish to the Selwyn River and other tributaries. The lower reaches of the incoming tributaries that flow into the lake provide important fish habitat.

31. Recently revised water conservation order rules for the opening of the lake have been implemented to take into account the requirements of diadromous fish[2] and the timing of opening the lake has been set to spring and / or autumn. This may be good for recruitment of the fisheries.

32. The lowland rivers tend to have greater fish diversity than inland sites, due to the fact that many of our native fish species are diadromous.

33. Native fish classified as threatened (Allibone et al 2010) in the catchment include Canterbury mudfish (*Neochanna burrowsius*) which has a nationally critical threat status. While other threatened fish in the catchment include longfin eel (*Anguilla dieffenbachia*), lamprey (*Geotria australis*), inanga (*Galaxias maculatus*), and torrentfish (*Cheimarrichthys fosteri*); all of these species have a declining threat status (Allibone et al 2010). Fresh water crayfish or koura (*Paranephrops planifrons*) are also recorded in the catchment and are a threatened species in gradual decline (Hitchmough et al. 2007).

34. Golders (2012) provide a comprehensive ecological assessment of some tributary streams of the Te Waihora Catchment.

35. Sites with high ecological value include Prices Stream and Kaituna River, which drain Banks Peninsula and are characterised by stony beds, healthy invertebrate fauna, and the presence of threatened native fish such as longfin eel, inanga and lamprey.

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[1] An **ecotone** is a transition area between two biomes. It is where two communities meet and integrate.
[2] Diadromous fish require migratory access to sea and freshwater to complete their lifecycle.

36. The hill-fed Selwyn River and its tributaries, the Hawkins and Hororata Rivers are also considered to have high ecological value, again due to the predominantly silt-free stony bed sediments, healthy invertebrate populations, and the presence of acutely threatened Canterbury mudfish populations in the upper catchment.

37. Harts Creek is one of the few spring-fed lowland streams that is considered to have high ecological values, as it supports brown trout spawning and adult trout habitat, plus it has a diverse native fish fauna, and has received substantial riparian enhancement and protection.

38. Minimum flow sites with relatively low ecological value include Baileys Stream, Snake Creek, Miles Drain, the Irwell River, and to a lesser degree Doyleston Drain. All of these waterways have significant sedimentation and many have low flows.

39. With the exception of the Selwyn River and its tributaries, most waterways in the catchment have high macrophyte (aquatic plant or weed) cover due to the combination of high nutrient concentrations, soft sediments, little shading and stable spring fed flows (Golder 2011).

40. In summer many of the small waterways are completely choked with macrophytes that reduce their value as flowing water habitat. This is because high macrophyte cover reduces water velocities, limits aquatic available habitat for fish and can result in low overnight oxygen concentrations.

41. The upper reaches of the Selwyn and Kaituna Rivers are the only sites with QMCI[3] greater than 6 indicative of excellent ecosystem health.

42. Mean QMCI scores are reduced at downstream sites indicating a downstream decline in ecosystem health. An exception to this is Boggy Creek, which shows similar QMCI scores at up stream and downstream sites.

43. Sediment deposition appears to be a key driver in lowering QMCI scores in the rivers and streams of the Te Waihora / Lake Ellesmere catchment (Golders 2011)

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[3] The QMCI is a biotic index of water and habitat quality used by most Regional Councils.

44. The current extent of wetland habitat in the catchment is minimal and primarily restricted to the shores of Te Waihora / Lake Ellesmere with scattered remnants throughout the plains and foothills and often occuring at the source of streams. Wetland habitats in the catchment are all modified to some extent, but they are ecologically significant because of the scarcity of wetlands on the Canterbury Plains.

45. Of particular significance is that wetlands are a key habitat for mudfish. Canterbury mudfish are only found in Canterbury and are acutely threatened with extinction. The Selwyn River catchment supports the largest and most significant known population of Canterbury mudfish with greatest numbers in the Hororata area, a large population has more recently been identified in the Waianiwaniwa Valley, and a small population is present in a tributary of Doyleston Drain.

STATE AND TRENDS OF LAKE ELLESMERE / TE WAIHORA CATCHMENT

46. Te Waihora/Lake Ellesmere is a highly turbid, wind exposed hypertrophic lake with a current trophic level index[4] of 6.8 (Gerbeaux and Ward 1991; Hamilton and Mitchell 1997; Schallenberg et al 2010). The water quality of Te Waihora and its riparian margins has deteriorated to an extent that the lake's mauri; its life force or capacity to sustain life has been significantly altered (Norton and Gibbs 2013). A literature review conducted by Burnett and Wallace (1973) indicates that Te Waihora has the most nutrient enriched water quality of any lake in New Zealand.

47. Prior to 1968 Lake Ellesmere had up to 80,000 black swans (Cygnus *atratus*), abundant submerged macrophytes and relatively higher water clarity (Hughes et al. 1974) amongst the macrophyte beds. In 1968 a severe storm (the Waihine) destroyed the submerged macrophyte beds and transformed the lake to an alternate state dominated by high concentrations of suspended sediment and phytoplankton (Gerbeaux 1993; Hamilton and Mitchell 1997). Submerged macrophyte populations have not recovered since the Waihine storm (Schallenberg et al 2010).

[4] The Trophic Level Index (TLI) is a commonly used measure of lake eutrophication developed by Burns et al 2000.

48. The change in autochthonous[5] production from macrophyte to phytoplankton dominated has resulted in changes to the macroinvertebrate fauna towards less energetically favorable species for fish growth. The reduction in fish growth has been particularly evident with respect to smaller (< 40 cm length) short fin eels of the lake (Kelly & Jellyman 2007). The changes to growth rates of other fish species and wading birds is not well understood.

49. Lake Ellesmere is classed as hypertrophic owing to its very high concentrations of total nitrogen, total phosphorus and chlorophyll a (phytoplankton).

50. I have analysed water quality of the lake data since 1993 which shows that the most representative site (mid lake) breaches all criteria for these three key water quality variables (phytoplankton chlorophyll a, total nitrogen and total phosphorus) with respect to the national bottom line of the national policy statement for freshwater management (2014).

51. Conversely total ammoniacal nitrogen[6] and *E.coli* concentrations show good compliance with the national bottom lines of the national policy statement for freshwater management 2014. While the lake shows good compliance with bathing standards, the public perception is that it is unsuitable for swimming. It is likely that this perception is driven by the poor water clarity and colour of the lake as well as occasional cyanobacteria phytoplankton blooms.

52. Temporal trend analysis of Lake Ellesmere water quality data shows that total nutrient concentrations (total nitrogen & total phosphorus) have declined since monitoring commenced in 1993. The analysis also shows that chlorophyll a concentrations have declined at two sites (Taumutu and Kaituna Lagoon). These results are consistent with previous analyses undertaken by Environment Canterbury (2012). The decline in nutrient concentrations could be due to more regular openings of the lake to sea as seawater is generally lower in nutrient concentrations than freshwater. However further analysis of salinity levels would need to be conducted to confirm this.

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[5] Autochthonous – organisms that attain their energy requirements from photosynthesis

[6] Ammoniacal nitrogen – a measure of the amount of ammonia in the water which is ,an essential nutrient but also can become toxic in high enough concentrations

53. State and trend analysis of the tributaries of the Te Waihora / Lake Ellesmere Catchment was undertaken by Golders in 2011. Key findings of this report were

- Daily maximum water temperatures in summer frequently exceed temperature guidelines for protection of aquatic life in lowland tributaries of Lake Ellesmere. No meaningful[7] temporal trends in temperature were evident at any of the sites.
- Dissolved oxygen concentrations frequently drop below NRRP objectives for protection of aquatic life in a number of lower catchment rivers. No meaningful temporal trends in temperature were evident at any of the sites.
- Nutrient concentrations in the lower catchment are elevated compared to the upper catchment sites and exceed guidelines for protection of aquatic ecosystem health. Three sites showed meaningful increases in nitrate nitrogen (Selwyn River, Hamner Road Drain and Harts Creek) while two sites (Kaituna River and Halswell River) show declining temporal trends in nitrate nitrogen. Meaningful increases in dissolved reactive phosphorus were evident at 3 sites (Halswell River, Hamner Road Drain and Harts Creek) while one meaningful decline in dissolved reactive phosphorus was evident at LII River. The reason for these water qualty trends is unclear, however they are considered environmentally significant.

54. When read in conjunction with the lake trend analysis it is clear that the dissolved nutrient concentrations of the tributaries have not affected temporal trends of total phosphorus or total nitrogen concentrations in the lake. In my view this is because most of the nutrient loading in the lake is created internally via nutrient recycling processes that are driven by the release of nutrient from the sediments.

CRITIQUE OF MITIGATION MEASURES

55. In my view many of the mitigation methods of the various scenarios are in fact experiments for which the outcome of their success is unknown. Of particular note are:

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[7] A meaningful temporal trend is one that not only shows statistical significance but also shows > 1% change / yr as an expression of the median.

56. The success of the alum dosing is dependent on pH. As the lake reaches very high pH in the summer (mid lake minimum , 7.9, maximum 8.7 n= 22) it is likely that alum sulfate dosing will have negligible effect in sequiestering Dissolved Reactive Phosphorus from the water column. Norton and Gibbs (2013) state that alum sulphate has a P binding capacity of 85 g/kg. Alum works best in the ph range of 4 to 6 and that above pH 6, the P-binding efficacy reduces falling to around 50% at pH 7.5 and around 20% at pH 8.5. While the lake data I have at hand is only for daily spot measurements, it at least identifies that there will be periods of the day when alum dosing will be highly ineffective. Some research of diel pH in Te Waihora has been done previously (Fisher, 2011, Wood 2008) reporting pH ranges of 8 and 10.08 and 7.7 and 9.2 respectively however more research is warranted to determine site specific diel variability of pH of the lake water column and sediments to gauge how successful alum dosing could be. I am sceptical that the lake provides an optimal pH for alum dosing to be effective.

57. The establishment of aquatic macrophyte beds around the periphery of the lake will be impeded by browsing of waterfowl, wave action, natural background turbidity, shading by phytoplankton and potential competition with macroalgae. In my view if the lake was suitable for aquatic macrophyte growth, then macrophytes would be growing there today, however all that remains are remnant areas with seed banks that seem to have low survival. Norton et al (2013) acknowledge that there is uncertainty of success and likelihood that restoration efforts will be set back occasionally by damage in severe storms while the potential for ephiphytic[8] periphyton to reduce light levels to the point where the macrophytes decline and senesce[9] (Bronmark & Weisner, 1992, Van donk, 1998; Petri, 2000) is well researched. Schallenberg (2013) cautions that macroalgae (e.g.Enteropmorpha, Cladophora, Bachelotia) may effectively outcompete the macrophytes during the rehabilitation process. If Council is serious about returning the lake margins to a macrohpyte

[8] Epiphyton are algae that can grow on aquatic macrophytes
[9] Senesce – die and decay

dominated system, they must address nutrient concentrations within the catchment otherwise phytoplankton will continue to dominate the lake. I concur with Norton and Gibbs (2013) when they state " A decision to attempt macrophyte restoration thus potentially brings multiple benefits but comes with uncertainty and the cost of several interventions".

58. The success of floating wetlands will depend upon wave action and an absence of floodwaters to ensure they do not get washed away or inundated.

59. Sediment removal from incoming tributaries – it is difficult to know how successful this will be.

60. The compounding adverse effects of climate change have not been considered in the modeling due to technicalities in predicting land use changes and tributary inflow characteristics. Norton et al (2014) state that "We can be less confident about the absolute state of the lake under any scenario in the long term, particularly given uncertainties around climate change".

61. There is a strong interdependency with some of these mitigation strategies particularly 1 - 3 above. Aquatic macrophytes will not establish unless the water becomes clear enough for them to thrive and if nutrient concentrations are greatly reduced (to shift phytoplankton towards severe nutrient limitation). This means that aquatic macrophyte rehabilitation will only occur if the alum dosing is successful in removing particulate matter from the water column AND the floating wetlands and other interventions for wave dampening and wetland rehabilitation is a complete success.

CRITIQUE OF MODELING

62. Norton et al (2014) used coupled deterministic models and experiments to inform the Selwyn Waihora collaborative community process for setting nutrient loading limits for Te Waihora / Lake Ellesmere. A number of nutrient loading and mitigation scenarios are run through the models to attempt to show how the lake would respond to various management strategies as represented by the scenarios.

63. While the model shows relatively good performance in terms of observed vs. expected values for many water quality variables. This

is not so for chlorophyll a and I concur with the author's comment that " The poor ability of the CAEDYM model to predict some key water quality parameters in the lake (e.g. Chlorophyll (a) highlights that caution should be exercised when interpreting the model outputs as predictions under the various scenarios".

64. I also concur with the author's statement that "There is considerable uncertainty associated with the effectiveness of the various mitigation methods and with the model informed assessment of effects scenarios." Norton et al also state "We can be less confident about the absolute state of the lake under any scenario in the long term, particularly given uncertainties around climate change."

65. It should be noted that the inputs for the coupled hydrodynamic ecological model (DYRESM-CAEDYM) have come from other modelled outputs that all contain some error. Therefore the error of one model becomes incorporated into the second model for which error is also likely. The effect of adding these additional errors could be additive or multiplicative to the error of the final ecological model.

66. When combining the sources of error prior to input to the coupled hydrodynamic ecological model, there are 4 modelled sources of error (NIWA CLUES model, Overseer, N loss look up table, lake water balance model) plus 9 further sources of error based on assumptions (success of mitigation methods of alum dosing, macrophytes establishment, floating wetlands, wetland enhancement, lake level management, good farm management practice, sediment removal from tributaries, performance of consented sewage treatment operations, phosphorus loss from the catchment).

CRITIQUE OF ECOLOGICAL FLOW LIMITS

67. In June 2012 Golder Associates published a technical report of the ecological values of 43 stream sites and recommended minimum flows for 28 low flow sites within the Te Waihora Catchment.

68. The authors classified the low flow sites according to high, moderate or low ecological value and where insufficient data was available declared the ecological value as unknown (Taumutu Creek at D/S Gulliver intake, Lee River at Brooklands, Tent Burn at Beachcroft, Jollies Brook at Bullocks Rd, Jollies Brook at outlet to sea, SDC water race (Rakaia), Unnamed Drain at Prendergast Property, Bridling's Brook at Leggs Rd).

69. The authors also demonstrated that current minimum flows are lower than recommended for protection of ecological values at many sites in the catchment. They also commented that "this trend is most evident for larger rivers (7 dMALF> 200 l/s) with 14 of the 17 larger rivers having lower than recommended minimum flows.

70. The authors recommended 90% of the naturalized[10] 7 day mean annual low flow for tributaries with less than 300 l/s MALF or between 70 – 90 % of the naturalized 7 day mean annual low flow for tributaries with greater than 300 l/s MALF.

71. The rationale for this categorisation of low flows stems from a previous Golders (2011) report, which stated that habitat availability for eels, declined at a greater rate at flows less than 300 l/s (Graynoth 2007). The low flows were derived from a combination of expert panel advice, the proposed national environmental standard and hydrodynamic habitat modelling.

72. I am of the opinion that a more appropriate regime would be to set minimum flows at naturalized 7 day MALF for all tributaries with < 300 l/s flow and 90% of naturalized 7 day MALF for all tributaries with > 300 l/s flow. The reason for this is:

1. With the exception of the larger tributaries (Selwyn,Birdlings Brook, Halswell River, Harts Creek, Lee River and Hawkins Rivers) hydrodynamic habitat modeling has not been done in the Te Waihora Tributaries (Golders 2011).

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[10] The naturalized mean annual low flow is the mean annual low flow that occurs over a 7 day period in the absence of any surface water abstraction.

2. The national environmental standard for setting flows is the minimum standard for flow setting. This standard requires all tributaries of the Te Waihora to have a low flow limit of 90% MALF as a minimum. Given that a strong directive of the Canterbury Water Management Strategy is to improve ecological health in all lowland streams in the region by 2040 it seems logical to have the NES as a standard for the larger trbituaries (> 300l/s) and MALF for the smaller tributaries as the smaller tributaries are more susceptible to habitat loss than the larger tributaries.
3. For eight sites the ecological values are unknown and more data is needed to assess this. Ecological flow setting should take into account the significance of the ecological values present and the flows required to sustain those values. Therefore a precautionary approach should apply to these systems as the ecological value of these systems is unknown.
4. Approximately half (14) of the low flow sites have particularly poor flow correlations with recorder sites (Clark, 2001). More gaugings are needed at these sites to improve the R^2 value[11] of the relationship with the recorder sites.
5. Two sites at Harts Creek are important trout spawning sites.
6. Having minimum flows higher than the proposed national environmental standard allows for adaptive management of these tributary systems in the future.

73. I concur with the Golders (2012) comment that “it is considered inappropriate to recommend low minimum flows for degraded waterways in the catchment, given that improved ecological health is a strong directive of the CWMS (and pCLWRP[12]) because low minimum flows could thwart attempts to improve ecological health via other activities such as reduced nutrient concentrations and improved riparian condition and instream habitat quality.”

74. I have appended my recommended low flow limits for existing low flow sites within the Te Waihora / Lake Ellesmere Catchment.

DUAL NUTRIENT MANAGEMENT

75. A key driver of phytoplankton, periphyton or aquatic macrophyte productivity is the presence of macronutrients (nitrogen and phosphorus) in water.

76. The nutrient (N or P) that is limiting growth is the one that when added to a water body will result in an increase in plant biomass. This

[11] The R^2 value is a statistical term commonly used to describe how well the data fits to a statistical model. For flow correlations it is a linear model that is used to describe the relationship between the recorder site and the non recorder site.
[12] Proposed Canterbury Land and Water Resource Management Plan objectives and strategic policies 4.2 – 4.10 (see evidence of Scott Pearson)

might be expressed as an increased chlorophyll a concentration of phytoplankton in a lake water sample or biomass of chlorophyll a having been sampled from periphyton stone scrapings of a rock or biomass of aquatic macrophytes sampled from a streambed.

77. To illustrate growth limitation you could consider a pot plant that needs light and water to grow; you can grow it in the best light possible, but if you do not water it then the plant will die. Water becomes the limiting resource because it is the scarcest resource; addition of any water (as long as the plant has not died) will result in the plant growing. Thus the resource (nutrient) that is at the lowest level in the water body is the one that can have the biggest impact. Management of that nutrient will therefore have the biggest effect on controlling plant growth (taken from Death 2013).

78. Nutrient limitation studies I have undertaken in Hawke's Bay using nutrient agar diffusing substrates have demonstrated that the same river can display N or P limitation or co limitation (N&P) during the course of a year. It is therefore important to manage both nitrogen and phosphorus concentrations in aquatic ecosystems to ensure that aquatic macrophyte, periphyton or phytoplankton biomass does not become too high. Excessive plant biomass can result in smothering of important macroinvertebrate habitat, or large diurnal swings in dissolved oxygen caused by photosynthesis during the day and plant respiration during the night.

79. A recent international meta-analysis study looking at the importance of nitrogen to water quality in shallow lakes reported that while chlorophyll-*a* and trophic status was more often controlled by P, macrophyte species composition and (in some cases) cover was related to in-lake TN concentration, with some species clearly having TN tolerances or preferences. This emphasises the importance of co-management of N and P for managing aquatic macrophyte communities in shallow lakes.

80. While dual nutrient management of Te Waihora / Lake Ellesmere has been acknowledged in Variation 1 with specific TN and TP limits set, this has not been the case for tributaries for which only nitrate nitrogen nutrient criteria have been specified.

81. Dual nutrient management is necessary for the incoming tributaries to ensure that the desired TLI of the lake is met. Gibbs and Norton (2013) note "a TLI score of less than 6 seems achievable in those areas, particularly if the external nutrient load is reduced by setting limits". As nutrients comprise both nitrogen and phosphorus species, I cannot see the rationale for Variation 1 to only specify tributary limits for nitrate nitrogen only.

82. In light of the comments above, it is my view that only managing one nutrient in the tributaries of Te Waihora / Lake Ellesmere catchment is negligent as it ignores the potential of phosphorus limited periphyton or aquatic macrophytes present in the rivers as well as ignores the overall goal of reducing nutrient concentrations and TLI value of the lake.

LAKE WATER QUALITY LIMITS OF PLAN VARIATION 1

83. Submerged macrophytes are very important structuring elements in lakes (Kelly & McDowall 2004), and may markedly affect the environmental conditions of a lake by their ability to stabilise the clear-water state (Scheffer & Jeppesen 1998). Thus the aim of shallow lake management is often to sustain or restore macrophyte communities to maintain the clear-water state of shallow lakes.

84. Loss of macrophyte communities from nutrient enrichment of lakes can occur via a number of mechanisms including; phytoplankton blooms, epiphyton growth, or intensive growths of tall macrophytes. All of these mechanisms generally result in shading of macrophyte communities causing light limitation of plants and their ultimate collapse, in a process termed 'flipping' (Schallenberg & Sorrell 2009).

85. In my view, Te Waihora / Lake Ellesmere will not become rehabilitated to a less degraded state unless nutrient concentrations are lower than those set in Variation 1. This is because nutrient rich water stimulates phytoplankton productivity and in conjunction with wind induced turbidity has the potential to shade out any aquatic macrophyte plantings.

86. Gerbeaux and Ward (1991) confirm that the reason for the lack of regeneration of macrophytes in Lake Ellesmere is generally attributed to the high turbidity (low water clarity) associated with

suspended sediments and phytoplankton proliferation as the external nutrient loads have increased.

87. Larned and Schallenberg (2006) acknowledge that most of the time phytoplankton productivity of the lake is light limited owing to the highly turbid conditions. The authors also conclude that with the exception of periods of high water transparency, nutrient macronutrient concentrations (N and P) usually exceed phytoplankton demands in the lake.

88. In a literature review Schallenberg (2013) investigated chlorophyll a concentrations and percentage macrophyte cover vs. total nitrogen concentrations from 10 intermittently closed and open lakes and lagoons (ICOLLs) and brackish coastal lakes in New Zealand. The author demonstrated that only those systems with ≤ 1 mg/l total nitrogen had any presence of aquatic macrophytes.

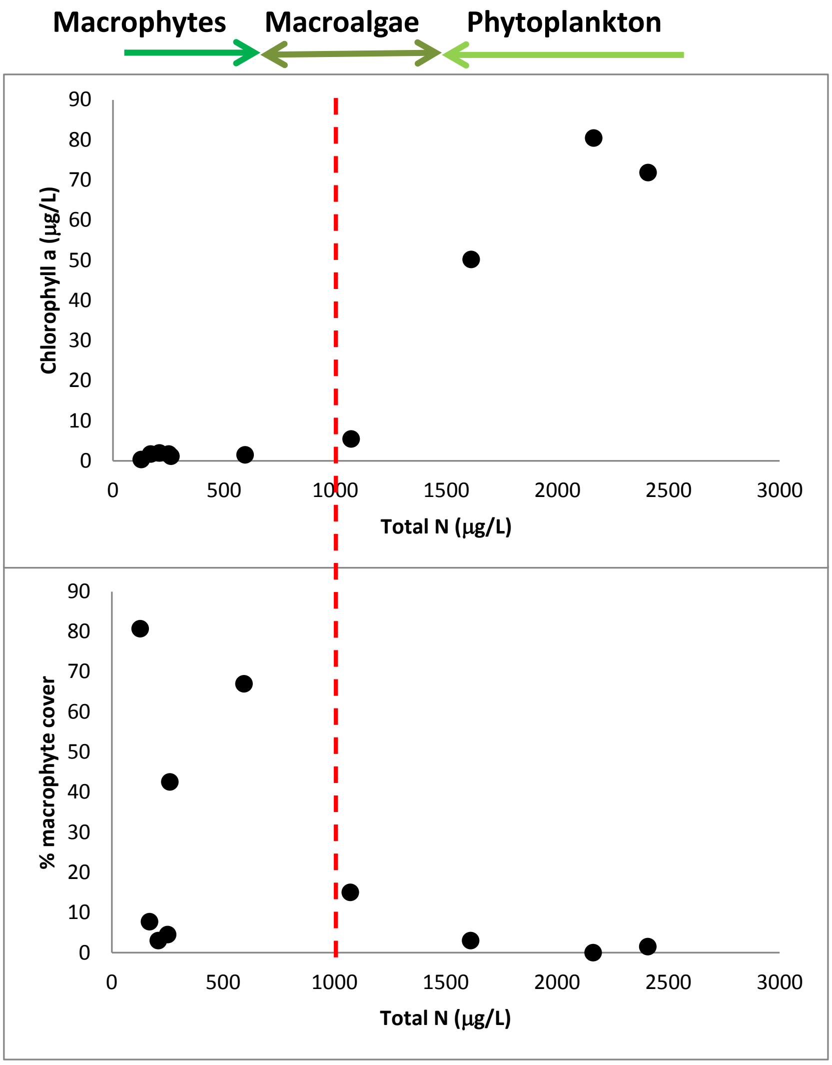

Fig. 3. Water column chlorophyll *a* concentrations (top panel) and percentage macrophyte cover (bottom panel) vs. total nitrogen concentration from 10 ICOLLs and brackish coastal lakes in New Zealand. The vertical red line indicates 1000 μg TN/L, a potential threshold delineating macrophyte- from phytoplankton-dominance. From the CDRP[13] data (Schallenberg unpubl. data).

89. In a similar investigation (Jeppesen *et al.* 2007) plotted macrophyte cover in 44 Danish lakes (over several years, 246 lake years) showing macrophyte cover in relation to in-lake TN concentrations). This analysis suggests that lakes with TN concentrations greater than 1,000 mg/m3 would have almost never have macrophyte cover > 50%, and lakes > 2000 mg/m3 never had macrophyte cover > 5%.

90. Kelly et al (2013) investigated nutrient loadings to shallow coastal lakes in Southland for sustaining ecological integrity values. The authors conducted a national and international literature review and also undertook modeling to assess nutrient loads of 19 shallow lakes in Southland.

91. Kelly et al (2013) found that in European lakes (Denmark, Netherlands, U.K), a critical threshold for TP occurred around 100 mg/m^3, with very few lakes above this threshold having macrophytes covering 50% of the lake bed. In contrast in the warmer North American lakes (Florida) this threshold was closer to 50 mg/m^3. The nitrogen threshold occurred around 1000 mg/m^3 in both European and North American lakes above which few lakes had macrophyte cover exceeding 50%. The international component of the literature review also found that while chlorophyll a and trophic status was more often controlled by P, macrophyte species composition and (in some cases) cover was related to in lake TN concentration with some species clearly having TN tolerances or preferences. This emphasizes the importance of co management of N and P for managing aquatic macrophyte communities in shallow lakes.

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[13] Cross Departmental Research Pool

92. Modeling undertaken by Kelly et al (2013) showed that ecological integrity variables (such as macrophyte and macroinvertebrate communities) also indicated that P loading was a more proximal variable relating to benthic communities of lakes. The results tend to indicate lower thresholds than results from overseas studies, with NZ lakes having loads resulting in mean summer TP concentrations of > 50 mg/m3 (and nearly always having little or no macrophyte cover). Macroinvertebrate community richness was even more sensitive to nutrient loading and declined linearly by nearly 42% (from 26 to 15 taxa) compared with reference condition lakes at the 50 mg/m^3 TP upper limit for macrophyte cover.

93. A priority outcome for the Selwyn Te Waihora Zone is Te Waihora / Lake Ellesmere is a healthy ecosystem. In view of the evidence I have just iterated, this outcome cannot be achieved unless TN concentrations are maintained below 1 g/m^3 and TP concentrations are maintained below 0.05 g/m^3 measured at the centre of the lake. This means that the TLI outcome would need to be lowered to reflect this lower trophic state (likely to be a TLI of 5.5). It is difficult to know what the phytoplankton concentrations in the lake would be at these nutrient criteria, therefore I have appended (Appendix 3) two tables for 2037 and 2050 specifying desired nutrient concentration outcomes for the 2037 and 2050 years but have left the chlorophyll a concentrations as per plan variation 1. I am recommending that these two tables replace table 11l of plan variation 1.

94. I would recommend that the hypolimnion criteria specified in Table 11b are deleted as Te Waihora / Lake Ellesmere and Muriwai/ Coopers Lagoon as these water bodies are shallow polymictic lakes, that do not thermally stratify so they do not contain a hypolimnion. The % Saturation of dissolved oxygen for mid lake for both water bodies (90% saturation) is appropriate as is a maximum water temperature of 19 C. I would recommend the suitability for contact recreation outcome be set at good rather than good – fair to demonstrate improvement that is needed for Te Waihora / Lake Ellesmere.

95. The remaining ecological health indicators of table 11b (water temperature and Lake SPI grade) are appropriate to achieve the Te

Waihora Zone Priority Outcome f: Te Waihora /Lake Ellesmere is a healthy ecosystem.

96. I would recommend that the TLI maximum annual average is changed to 5.5 (mid lake), and 5.0 for Lake margins) to ensure that the Te Waihora Zone Priority Outcome f: Te Waihora /Lake Ellesmere is a healthy ecosystem is met. An amended table is provided in Appendix 4.

97. Gibbs and Norton (2013) note that lake modeling predicts that a 50% decrease in the current load of both TN and TP is needed to improve water quality to achieve current proposed plan objectives[14]. “This includes the need for a 50% reduction in the internal load of P (i.e. water column P derived from lake bed sediment from historic land use)”. Norton et al (2012) also states that analysis of relationships between TN load and the state of macrophytes in other similar lakes suggests that load reductions of more than 40% of current TN load would be needed to create nutrient conditions favoring returning the lake from its current phytoplankton dominated state to a self sustaining macrophyte dominated state.

98. Norton and Gibbs (2013) stress the importance in lowering nutrient loads in supporting any eutrophication mitigation measures in stating “the lower the nutrient load limits, the more effective the eutrophication mitigation actions and the better the outcomes for the lake and its associated values”.

RIVER WATER QUALITY LIMITS OF VARIATION 1

99. I would like to start with Table 11(a) of Variation 1 and provide my views on the management units, and ecological and microbiological health indicators listed in that table.

100. The management units for the rivers and streams of the Selwyn Waihora Catchment Rivers have been derived from a modified version of the New Zealand River Environment Classification (Snelder et al 2004). This is an appropriate way to classify the river and stream types for the purposes of the plan.

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[14] The currernt plan variation objective is for a Trophic Level Index of 6 or less. The current mean annual TLI in Te Waihora mid lake is 6.8.

101. The QMCI thresholds for the management units are appropriate however there is lack of consistency with respect to achieving compliance. For example the hill fed lower systems require 80% of samples for the Selwyn River/ Waikirikiri and Hawkins river and 60% of samples for the Waianiwaniwa over a 5 year period. Spring fed plain streams require 80% of samples over a 5 year period, while other rivers require 100% compliance based on a growing data set (no time period specified). In my opinion, sub clauses 2 and 7 should be removed as there should be no reason to relax compliance conditions for some streams over others. A prime outcome for Selwyn Te Waihora Zone is healthy lowland streams, this can only be achieved if compliance criteria of Variation 1 are applied consistently to each site.

102. The dissolved oxygen minimum saturation percentages set for the management units are appropriate.

103. Water temperature thresholds for the management units need review particularly with respect to hill fed upland, hill fed lower, Banks Peninsula and spring fed plain streams. This is because many of these management units should naturally have maximum water temperatures well below 20C (alpine upland, hill fed upland, spring fed plains) or they contain important trout spawning habitat (hill fed lower – Hawkins River, Selwyn / Waikirikiri, Banks Penninsula Kaituna spring fed plains – Halswell River, Harts Creek, Hororata River, Irwell River, Lee River, LII river and Tent Burn Stream). I would recommend that a temperature maximum of 18 be set for all management units to ensure that the Selwyn Te Waihora Zone priority outcome of healthy lowland streams is met.

104. In my view the macrophyte and periphyton indicators should be discarded from Table 11(a). This is because periphyton and to a lesser degree aquatic macrophyte growths can change a lot over a short time period. Death (2013) states that periphyton is extremely variable in space and time and thus very difficult to monitor for environmental management. A less spatially and temporally variable index is the MCI (Macroinvertebrate Community Index) which is intimately linked with periphyton levels. I concur with this view.

105. The suitability for contact recreation grade is an appropriate microbiological indicator for Variation 1. However I would recommend all sites have a minimum standard of good to meet the sub outcome F4 "Recreation opportunities are improved". An amended version of table LLa is provided in Appendix 5.

106. I disagree with the nitrate nitrogen concentrations specified in Table 11(k) for the following reasons:

107. The animals are tested in a laboratory environment that is devoid of other multiple stressors that occur naturally in a river or stream environment (e.g. warm water temperatures, low dissolved oxygen concentrations, extensive periphyton or macrophyte growths, sedimentation, habitat degradation, freshes floods etc.). These other stressors could act in synergy to produce a toxic effect at a far lower concentration than a single toxicant in the laboratory.

108. The threshold effects are based on a data set describing chronic (long term) effect for a range of species groups that are considered to be representative of the aquatic ecosystem. The question then arises are the animals tested truly representative of the aquatic ecosystem of the Te Waihora Catchment. In the latest nitrate toxicity effects report (Hickey 2013) concludes that the database is relatively limited in native species with only seven species resident in New Zealand and two native species (mayfly and inanga). Based on this, it is difficult to have confidence in what the effects might be on the entire spectrum of invertebrates and fish of the Te Waihora Catchment.

109. Nitrogen and co limited (N&P) algae and aquatic plants are likely to form extensive mats at concentrations far lower than those specified for nitrate toxicity. This can lead to a smothering of preferential habitat for sensitive aquatic macroinvertebrates as well as create large swings in diurnal (daily) dissolved oxygen concentrations making it unsuitable for the fauna to survive. Furthermore extensive macrophyte mats can create areas of anoxia (low dissolved oxygen environments) within the mat, which could also provide unsuitable conditions for sensitive aquatic macroinvertebrates to survive. I concur with the statement made by Death (2013) "Nitrate nitrogen should be managed for ecological

health levels not toxicity. Significant adverse effects on life supporting capacity will occur long before the toxic effects of nitrates will be observed".

110. In a recent case (Ruataniwha Plains Water Storage Scheme Hearing) Associate Professor Russell Death (2013) gave a good analogy of the effects of nitrate nitrogen on aquatic ecosystems versus the effects of alcohol on people. "Although some nutrients (i.e. nitrate and ammonia) can be directly toxic to aquatic species the significant detrimental effects on ecosystem health occur long before toxic levels of these chemicals are reached. I liken this to the effect of alcohol, long before someone consumes so much alcohol they are poisoned, one will usually become very unhealthy."

111. As evidenced earlier, dual nutrient management is necessary for the control of undesirable biological growths in rivers in order to protect healthy functioning aquatic ecosystems. I would therefore recommend that dissolved reactive phosphorus limits are placed in Variation 1.

112. The following table shows how the current nitrate nitrogen concentrations of individual rivers and streams compare to the nutrient criteria outcomes specified in plan variation 1. The statistics I present overleaf have been derived from Ecan's rivers state of the environment monitoring programme. In addition to the median and 95th percentile value I have also shown the sample size for each site (n).

Management Unit	Site Name	Nitrate Nitrogen n	Nitrate Nitrogen median (mg/l)	Percentile 95 (mg/l)	Plan Variation 1 Outcome Median (mg/l)	Variation 1 Outcome 95th Percentile (mg/l)
Banks Peninsula	Kaituna Stream	259	0.11	0.54	1	1.5
Hill Fed Upland	Selwyn River @ Whitecliffs	103	0.21	0.45	1	1.5
Hill Fed Lower	Hawkins River Deans Rd	61	2.3	3.8	2.4	3.5
Hill Fed Lower	Selwyn River@ Coes Ford	344	**4.75**	**6.1**	2.4	3.5
Hill Fed Lower	Waireka River Auchenflower Rd	42	0.33	1.8	2.4	3.5
Spring Fed Plains	LII Stream	258	3.3	4.2	6.9	9.8
Spring Fed Plains	Irwell River @ Lake Rd	197	0.8	3.5	6.9	9.8
Spring Fed Plains	Hamner Rd Drain	233	2.3	4.8	6.9	9.8
Spring Fed Plains	Boggy Creek @ Lake Rd	118	5.4	8.9	6.9	9.8
Spring Fed Plains	Doyleston Drain Lake Rd	232	3.4	6.9	6.9	9.8
Spring Fed Plains	Harts Creek - Lower Lake Rd	235	4.5	6.9	6.9	9.8
Spring Fed Plains	Halswell River McCartneys Bridge	253	3.2	4.1	6.9	9.8
Spring Fed Plains	Jolllies Brook Bullocks	45	1	2.4	6.9	9.8
Spring Fed Plains	Lee River on Brooklands Farm	60	2.7	4.4	6.9	9.8
Spring Fed Plains	Waikewai Creek	63	3.6	5.5	6.9	9.8

Table 1: Comparison of plan variation 1 outcome criteria with individual river and streams of the Te Waihora Catchment.

113. Table 1 shows that the all sites except Selwyn River at Coes Ford have nitrate nitrogen concentrations well below the plan variation nitrate nitrogen outcome criteria. Table 1 also shows that a lot of variability of nitrate concentration exists within each management unit. For example the Spring Fed Plains Management unit's lowest median nitrate nitrogen concentration is 0.8 mg/l (Irwell River at Lake Rd) and its highest median nitrate nitrogen concentration is 5.4 mg/l (Boggy Creek at Lake Rd). This means that applying a blanket nitrate nitrogen criteria for spring fed plains of median 6.9 mg/l and 95th percentile 9.8 mg/l (plan variation 1) would enable greater nitrate nitrogen contamination increases in some tributaries compared to others. This is likely to be viewed as an unfair system by landowners.

114. In my view an appropriate outcome for each individual river listed previously should be its current state based on the summary statistics I have provided from the state of the environment monitoring program. In my view the overall objective should be to maintain or enhance these riverine systems.

115. The following table shows the median and 95th percentile for dissolved reactive phosphorus concentrations of rivers and streams of the Te Waihora Catchment.

Management Unit	**Site Name**	**Dissolved Reactive Phosphorus n**	**Dissolved Reactive Phosphorus Median (mg/l)**	**Dissolved Reactive Phosphorus 95th Percentile (mg/l)**
Banks Peninsula	Kaituna Stream	258	0.02	0.04
Hill Fed Upland	Selwyn River @ Whitecliffs	103	0.005	0.01
Hill Fed Lower	Hawkins River Deans Rd	61	0.01	0.02
Hill Fed Lower	Selwyn River@ Coes Ford	343	0.01	0.04
Hill Fed Lower	Waireka River Auchenflower Rd	42	0.03	0.06
Spring Fed Plains	LII Stream	258	0.02	0.08
Spring Fed Plains	Irwell River @ Lake Rd	197	0.01	0.16
Spring Fed Plains	Hamner Rd Drain	232	0.03	0.15
Spring Fed Plains	Boggy Creek @ Lake Rd	118	0.02	0.13
Spring Fed Plains	Doyleston Drain Lake Rd	231	0.03	0.16
Spring Fed Plains	Harts Creek - Lower Lake	235	0.01	0.02
Spring Fed Plains	Halswell River McCartneys Bridge	252	0.03	0.06
Spring Fed Plains	Jolllies Brook Bullockds Rd	45	0.005	0.01
Spring Fed Plains	Lee River on Brooklands Farm	60	0.01	0.01
Spring Fed Plains	Waikewai Creek Gullivers Waikewai Creek	63	0.01	0.03

Table 2: Dissolved reactive phosphorus concentrations at selected sites of the Te Waihora Catchment.

116. Table 2 also shows that there is less variability of dissolved reactive phosphorus concentrations within each management unit compared to nitrate nitrogen. For example the Hill Fed Lower Management unit's lowest median dissolved reactive phosphorus concentration is 0.01 mg/l (Hawkins or Selwyn River) and its highest median dissolved reactive phosphorus concentration is 0.03 mg/l (Waireka River).

117. In my view the most appropriate outcomes should be river specific based on the criteria I have outlined above using Ecan's state of the environment monitoring data. I also support the Fish and Game interim recommendation that these nutrient concentrations are reduced by 30% by 2037 and reduced by a further 20% by 2050. This would ensure that the nutrient loadings entering the lake are reduced to ensure that future mitigation strategies have a greater likelihood of success as well as ensuring that the aquatic ecosystems of the entire catchment are protected. I have tabled these future outcome concentrations in Appendix 2.

Brett Stansfield

29 August 2014

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APPENDIX 1: RECOMMENDED MINIMUM FLOWS FOR EXISTING MINIMUM FLOW SITES

SITE	7 DAY MALF (l/s)	PLAN VARIATION 1	RECOMMENDED MINIMUM FLOW (l/s)
Kaituna River @ Kaituna Valley Rd*	35	32	35
Hawkins River @ Willows-Dalethorpe Rd*	37	33	37
Selwyn River @ Whitecliffs*	792	713	713
Selwyn River @ Coes Ford*	750	675	675
Hororata River @Halden Water Race Bridge*	424	382	382
Knights Creek @ Jiesons Property*	253	228	253
Halswell River @ Leadleys Rd~	582	407	524
Halswell River @ Ryans Bridge~	760	532	684
Halswell River @ Tobecks Bridge~	934	654	841
Haslwell River @ Neills Rd~	926	648	833
Halswell River @ Hodgens Bridge~	1157	810	1041
L-II river @ Pannetts Rd~	1820	1274	1638
L-II River @ Wolfes Rd~	1771	1240	1594
Baileys Creek @ Lincoln Leeston Rd*~	13	12	13
Silverstream @ Lincoln	88	79	88

Leeston Rd*~			
Snake Creek @ Lincoln Leeston Rd*~	70	63	70
Miles Drain @ Pannets Rd*~	14	13	14
Irwell River @ Lake Rd~	910	637	819
Hamner Rd Drain @ Lower Lake Rd	369	258	332
Boggy Creek @ Lake Rd*	290	261	261
Doyleston Drain @ D/S Lake Rd*	6	5	6
Birdlings Brook @ Locheads Rd	685	480	617
Birdlings Brook @ Leggs Rd	637	446	573
Harts Creek @ Lower Lake Rd	1068	748	961
Harts Creek @ Timber Yard Rd	1370	959	1233
Waikewai Creek @ Taumutu Beach*	38	34	38
Lee River @ Temoana~	935	655	841
Jollies Brook @ outlet to sea~	424	297	381

Key: * = Flow sensitive sites

~ = Sites display poor correlation with recorder sites

BoldText = sites are important trout spawning sites

APPENDIX 2: OUTCOME NUTRIENT CONCENTRATIONS NEEDED BY 2037. Dissolved Reactive Phosphorus (mg/l)

Management Unit	**Site Name**	**Dissolved Reactive Phosphorus Median (mg/l)**	**Dissolved Reactive Phosphorus 95th Percentile (mg/l)**
Banks Peninsula	Kaituna Stream	0.013	0.03
Hill Fed Upland	Selwyn River @ Whitecliffs	0.0035	0.007
Hill Fed Lower	Hawkins River Deans Rd	0.007	0.014
Hill Fed Lower	Selwyn River@ Coes Ford	0.007	0.028
Hill Fed Lower	Waireka River Auchenflower Rd	0.021	0.042
Spring Fed Plains	LII Stream	0.014	0.056
Spring Fed Plains	Irwell River @ Lake Rd	0.007	0.112
Spring Fed Plains	Hamner Rd Drain	0.021	0.105
Spring Fed Plains	Boggy Creek @ Lake Rd	0.014	0.091
Spring Fed Plains	Doyleston Drain Lake Rd	0.021	0.112
Spring Fed Plains	Harts Creek - Lower Lake	0.007	0.014
Spring Fed Plains	Halswell River McCartneys Bridge	0.021	0.042
Spring Fed Plains	Jolllies Brook Bullockds Rd	0.003	0.007
Spring Fed Plains	Lee River on Brooklands Farm	0.007	0.007
Spring Fed Plains	Waikewai Creek Gullivers	0.007	0.021

OUTCOME NUTRIENT CONCENTRATIONS NEEDED BY 2037. NITRATE NITROGEN (mg/l)

Management Unit	**Site Name**	**Nitrate Nitrogen Median (mg/l)**	**Nitrate Nitrogen 95th Percentile (mg/l)**
Banks Peninsula	Kaituna Stream	0.08	0.38
Hill Fed Upland	Selwyn River @ Whitecliffs	0.15	0.32
Hill Fed Lower	Hawkins River Deans Rd	1.6	2.7
Hill Fed Lower	Selwyn River@ Coes Ford	3.3	4.3
Hill Fed Lower	Waireka River Auchenflower Rd	0.23	1.3
Spring Fed Plains	LII Stream	2.3	2.9
Spring Fed Plains	Irwell River @ Lake Rd	0.6	2.5
Spring Fed Plains	Hamner Rd Drain	1.6	3.4
Spring Fed Plains	Boggy Creek @ Lake Rd	3.8	6.2
Spring Fed Plains	Doyleston Drain Lake Rd	2.4	4.8
Spring Fed Plains	Harts Creek - Lower Lake Rd	3.1	4.8
Spring Fed Plains	Halswell River	2.24	2.9
Spring Fed Plains	Jolllies Brook Bullockds Rd	0.7	1.7
Spring Fed Plains	Lee River on Brooklands Farm	0.08	0.38
Spring Fed Plains	Waikewai Creek Gullivers	0.15	0.32

OUTCOME NUTRIENT CONCENTRATIONS NEEDED BY 2050. Dissolved Reactive Phosphorus (mg/l)

Management Unit	**Site Name**	**Dissolved Reactive Phosphorus Median (mg/l)**	**Dissolved Reactive Phosphorus 95th Percentile (mg/l)**
Banks Peninsula	Kaituna Stream	0.01	0.02
Hill Fed Upland	Selwyn River @ Whitecliffs	0.003	0.005
Hill Fed Lower	Hawkins River Deans Rd	0.005	0.01
Hill Fed Lower	Selwyn River@ Coes Ford	0.005	0.02
Hill Fed Lower	Waireka River Auchenflower Rd	0.015	0.03
Spring Fed Plains	LII Stream	0.01	0.08
Spring Fed Plains	Irwell River @ Lake Rd	0.01	0.08
Spring Fed Plains	Hamner Rd Drain	0.015	0.075
Spring Fed Plains	Boggy Creek @ Lake Rd	0.01	0.07
Spring Fed Plains	Doyleston Drain Lake Rd	0.015	0.08
Spring Fed Plains	Harts Creek - Lower Lake Rd	0.005	0.01
Spring Fed Plains	Halswell River	0.015	0.03
Spring Fed Plains	Jolllies Brook Bullockds Rd	0.003	0.005
Spring Fed Plains	Lee River on Brooklands Farm	0.005	0.005
Spring Fed Plains	Waikewai Creek Gullivers	0.005	0.015

OUTCOME NUTRIENT CONCENTRATIONS NEEDED BY 2050. NITRATE NITROGEN (mg/l)

Management Unit	**Site Name**	**Nitrate Nitrogen Median (mg/l)**	**Nitrate Nitrogen 95th Percentile (mg/l)**
Banks Peninsula	Kaituna Stream	0.06	0.27
Hill Fed Upland	Selwyn River @ Whitecliffs	0.10	0.23
Hill Fed Lower	Hawkins River Deans Rd	1.2	1.9
Hill Fed Lower	Selwyn River@ Coes Ford	2.4	3.0
Hill Fed Lower	Waireka River Auchenflower Rd	0.17	0.9
Spring Fed Plains	LII Stream	1.7	2.1
Spring Fed Plains	Irwell River @ Lake Rd	0.4	1.8
Spring Fed Plains	Hamner Rd Drain	1.2	2.4
Spring Fed Plains	Boggy Creek @ Lake Rd	2.7	4.5
Spring Fed Plains	Doyleston Drain Lake Rd	1.7	3.5
Spring Fed Plains	Harts Creek - Lower Lake Rd	2.3	3.5
Spring Fed Plains	Halswell River	1.6	2.0
Spring Fed Plains	Jolllies Brook Bullockds Rd	0.5	1.2
Spring Fed Plains	Lee River on Brooklands Farm	1.4	2.2
Spring Fed Plains	Waikewai Creek Gullivers	1.8	2.8

APPENDIX 3: DESIRED OUTCOMES FOR TE WAIHORA / LAKE ELLESMERE AND COOPERS LAGOON FOR 2037

LAKE	LOCATION	TARGET			
		TLI	TP	TN	Chl a
Te Waihora / Lake Ellesmere	Mid Lake	6.0	0.07	2.2	74
	Margins	5.5			
Coopers Lagoon		4	0.020	0.34	5
As a maximum annual average			(mg/l)	(mg/l)	(**µg/** l)

DESIRED OUTCOMES FOR TE WAIHORA / LAKE ELLESMERE AND COOPERS LAGOON FOR 2050

LAKE	LOCATION	TARGET			
		TLI	TP	TN	Chl a
Te Waihora / Lake Ellesmere	Mid Lake	5.5	0.05	1.0	74
	Margins	5.0			
Coopers Lagoon		4	0.020	0.34	5
As a maximum annual average			(mg/l)	(mg/l)	(**µg/** l)

APPENDIX 4: FRESHWATER OUTCOMES FOR SELWYN WAIHORA CATCHMENT LAKES

Management Unit	Lake	Ecological Health Indicators			Eutrophication Indicator	Visual Quality Indicator	Microbiological Indicator	Cultural Indicator
Coastal Lakes		Dissolved Oxygen	Temperature (maximum) C	Lake SPI	Trophic Level Index (maximum annual average)	Water Clarity	Suitability for contact recreation (SFRG)	Freshwate4r mahinga kai species are sufficently abundant for custormaty gathering water quality is suitable for their safe harvesting and they are safe to eat.
	Te Waihora / Lake Ellesmere	90	19 (mid lake)	Moderate	5.5 (Mid lake) 5.0 (Lake Margins)	Clarity is greater in the lake margins than mid lake areas	Good	
	Muriwai / Coopers Lagoon	90	19	Moderate	4.0	No value set	No Value Set	

APPENDIX 5: RECOMMENDED CRITERIA FOR TABLE 11L OF PLAN VARIATION 1

Management Unit	River	Critical Values[ci1]	QMCI [minimum score]	Dissolved oxygen [minimum daily saturation] (%)	Temperature [max]	Suitability for contact recreation (SFRG)
Natural State	Headwaters of Selwyn / Waikirikiri	High biodiversity, High amenity, Natural character	Rivers are maintained in a healthy state			
Alpine – Upland	Headwaters of Selwyn/ Waikirikiri	High biodiversity Salmonid Fishery	6	90	18	Good
Hill-fed Upland	Upper Selwyn/Waikirikiri Hawkins	High Biodiversity Salmonid Fishery	6	90		Good
Hill-fed Lower	Hawkins Hororata Selwyn/Waikirikri Waianiwaniwa	Salmonid Fishery Amenity Contact recreation	5	90	18	Good
Banks Peninsula	Kaituna Prices Stream	High Biodiversity	5 6	90	18	Good

Spring-fed – plains	Birdlings Brook Boggy Creek Doyleston Drain Halswell/ Huritini Hanmer Road Drain Harts Creek Hororata Irwell River Jollies Brook Knights Creek Lee LII Lower Selwyn/ Waikirikiri Silverstream Snake Creek Taumutu Creek Tent burn Stream Waikekewaia Creek and other Lowland Spring fed streams	Moderate Biodiversity Salmonid Fishery	5	70	18	No Value set