IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	applications by Central Plains Water Trust to: Canterbury Regional Council for resource consents to take and use water from the Waimakariri and Rakaia Rivers and for all associated consents required for the construction and operation of the Central Plains Water Enhancement Scheme Selwyn District Council for resource consents to construct and operate the Central Plains Water Enhancement Scheme
AND	
IN THE MATTER OF	a notice of requirement by Central Plains Water Limited to: Selwyn District Council for the designation of land for works associated with the construction and operation of the Central Plains Water Enhancement Scheme

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SUPPLEMENTARY EVIDENCE OF GREGORY PETER BURRELL
RESPONSE TO ISSUES RAISED IN THE ECAN OFFICER REPORT

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INTRODUCTION

1. My name is Gregory Peter Burrell. My qualifications and experience, and the basis on which I prepared this brief, are set out in my main brief of evidence prepared for this hearing (dated January 2008).

2. I have read the code of conduct for expert witnesses set out in the Environment Court practice note, and I confirm that I have complied with the code in the preparation of my evidence.

SCOPE OF EVIDENCE

3. The purpose of this supplementary evidence is to respond to issues raised in the S41C report of Ned Norton and Vince Bidwell, dated October 2009. The key issues I am responding to relate to effects of the proposed revised Central Plains Water Enhancement Scheme (CPW) on the water quality and ecology of lowland streams and Lake Ellesmere/Te Waihora.

4. In preparing this supplementary brief I have relied upon or referred to the following relevant information sources:

- Water quality and ecological monitoring data and reports I have already discussed to date in the hearing;
- Recent water quality assessments associated with irrigation development for the Hunter-Downs Irrigation Scheme (Norton et al. 2007) and the upper Waitaki catchment (GHD 2009); the draft Canterbury Water Management Strategy; and the Te Waihora modelling evidence of Professor David Hamilton.
- Cliff Tipler's October 2009 supplementary evidence regarding phosphorus runoff and leaching.
- The Bidwell & Norton (2009) S41C report.

EFFECTS ON LOWLAND STREAMS

5. The key criticism Bidwell & Norton (2009) make of the technical water quality and ecology evidence presented to date for CPW is that there has been a lack of quantitative assessment of effects of the CPW scheme on surface water quality and the ecology of lowland streams and Te Waihora. For lowland streams, Bidwell & Norton (2009) suggest three “tests” against which the effects of the CPW scheme could be assessed:

- The provisions of the proposed Natural Resources Regional Plan (PNRRP).
- Nutrient enrichment guidelines.
- Recently revised nitrate toxicity guidelines.

In addition to the above tests, Bidwell & Norton (2009) questioned the applicant’s assumption that phosphorus loss from the CPW area was not a significant issue.

6. In the following sections, I use quantitative data to assess the effects of the CPW scheme on lowland streams, using each of the three tests of Bidwell & Norton (2009). In his supplementary evidence of October 2009, Cliff Tipler discussed the matter of phosphorus loss from the CPW area and his conclusions are that the potential amount of phosphorus lost from the CPW area would be very small, that mitigation would be very effective, and that nitrate leaching is of more of a concern.

PNRRP Objectives and Nutrient Enrichment

7. Although it is not yet operative, the objectives and standards in the PNRRP and its variations are often used by ECan to assess effects of consent applications. In my opinion, the key relevant test for CPW effects on surface waters in relation to the PNRRP is whether Objective WQL1 will be met. The key WQL1 outcomes of relevance here are:

- Bed coverage with emergent macrophytes not to exceed 50%.
- Bed coverage with thick algal mats (>3 mm) not to exceed 60%.
- Bed coverage with filamentous algae (>2 cm) not to exceed 30%.
- Maximum of 200 mg/m^2 of chlorophyll *a* (a measure of periphyton biomass).

8. I note that the periphyton cover and biomass outcomes are taken directly from the Ministry for the Environment (MfE) periphyton guidelines (Biggs 2000). The periphyton guidelines state that 60% bed coverage with thick mats is broadly equivalent to 200 mg/m² of chlorophyll *a* and that 30% cover with long filamentous algae is equivalent to 120 mg/m² of chlorophyll *a*. The periphyton guidelines provide empirical formulae that can be used to predict maximum chlorophyll *a* biomass based on monthly average nutrient data and accrual length (i.e., the average number of days between floods that are capable of washing away periphyton biomass). In the absence of any equivalent guidelines or models for predicting macrophyte cover from nutrient concentrations, in the following sections I have used the periphyton guidelines to assess compliance with PNRRP Objective WQL1.

9. The two periphyton biomass models given in Biggs (2000) are:

- Equation 1: Log10 (maximum chl. a) = 4.285 x (Log10 days of accrual) – 0.929 x (Log10 days of accrual)^2 + (0.504 x Log10 DIN) – 2.946
- Equation 2: Log10 (maximum chl. a) = 4.716 x (Log10 days of accrual) – 1.076 x (Log10 days of accrual)^2 + (0.494 x Log10 DRP) – 2.741

Where DRP is dissolved reactive phosphorus and DIN is dissolved inorganic nitrogen.

The Use of Models in Predicting Ecological Effects

10. In their report, Bidwell & Norton (2009) refer to the effects assessments associated with the Hunter Downs Irrigation Scheme (Norton et al. 2007) and the upper Waitaki catchment (the most recent being by GHD 2009) as being the sort of approach CPW should have used to assess effects in the Te Waihora catchment. In my opinion, modelling the effects of nutrient increases is most useful when the ecological outcomes of increasing nutrient concentrations are uncertain and when there is a particular risk of degrading the trophic state of a waterway (e.g., shifting it from a low nutrient, oligotrophic state to a nutrient-enriched eutrophic state). This was the case for both the Hunter Downs and upper Waitaki studies, as outlined below, but in my opinion this is not the case for the Te Waihora catchment.

11. In the Hunter Downs consent application, the irrigation area covered a very long stretch of the Canterbury lowlands and there was scant long term water

quality monitoring data available for many streams draining the irrigation area. The applicant therefore used a combination of short term water quality monitoring and nutrient limitation assays to assess nutrient limitation and effects of increasing nutrients on periphyton in lowland streams (Norton et al. 2007). I note that in the case of Hunter Downs, average measured nitrate plus nitrite nitrogen (NOx-N) concentrations in the four streams modelled ranged from 0.041 to 0.458 g/m³ and average DRP concentrations at the four sites ranged from 0.003 to 0.007 g/m³. As such, nutrient limitation could be expected to occur on occasions in these streams, with phosphorus being the most likely limiting nutrient.

12. The upper Waitaki catchment water quality report (GHD 2009) presents mean NOx-N concentrations from 20 sites in the upper Waitaki catchment. In my opinion, the upper Waitaki water quality dataset has two important points of difference from that of the Te Waihora tributaries. Firstly, most of the nutrient monitoring data is based on fewer than 10 samples for each site. Secondly, nutrient concentrations in the upper Waitaki tributaries were much lower than in the Te Waihora catchment; the range of mean NOx-N concentrations at the 20 sites ranged from <0.002 to 0.44 g/m³; however, the majority of sites (16 out of 20) had NOx-N concentrations <0.1 g/m³. Mean DRP concentrations ranged from <0.004 to 0.035 g/m³, with 19 of the 20 sites having DRP concentrations <0.02 g/m³ and 17 out of 20 sites have mean concentrations <0.008 g/m³.

13. Based on existing nutrient concentrations in the upper Waitaki catchment and the Hunter Downs irrigation area, nutrient limitation could occur at some sites, and the applicants therefore used formulae from the periphyton guidelines (Biggs 2000) to predict nutrient effects on periphyton cover. I note here that the formulae provided in the periphyton guidelines were based on a study of 30 hill/runoff-fed sites and lake-fed or spring-fed sites were expressly avoided. Monthly mean DIN concentrations ranged from 0.006 to 0.232 g/m³ and DRP ranged from 0.002 to 0.031g/m³ (Biggs 2000).

14. In contrast to the upper Waitaki and Hunter Downs water quality assessments, and the research on which the periphyton guidelines were based, mean nutrient concentrations for the Te Waihora tributaries are very high, ranging from 1.0 to 5.4 g/m³ (Irwell and Boggy Creek) for DIN and from 0.011 to 0.047 g/m³ (Harts Creek and Doyleston Drain) for DRP. Also, there is a very extensive water quality monitoring dataset available for the Te Waihora streams; with the

exception of Boggy Creek, all of the monitoring data used in the assessments and in this evidence is based on >150 data points and over 12 years of monitoring data. Dissolved inorganic nitrogen concentrations encountered in all of the Te Waihora tributaries exceed the concentrations in the 30 streams sites used to derive the periphyton guidelines and are indicative of existing highly eutrophic conditions (as discussed further below).

15. The key points that I would make from this comparative review of the studies referred to by Bidwell & Norton (2009) are that:

- Te Waihora stream tributaries have a far greater monitoring record than those on which the Hunter Downs and upper Waitaki assessments were based on. Therefore greater confidence can be had in the ability to generalise from monitoring data.

- While modelling could be used to assess potential changes of trophic state in the upper Waitaki and Hunter Downs assessments, this is of limited value in the Te Waihora catchment, where nutrient concentrations are already indicative of eutrophic conditions.

- Application of the periphyton biomass model used in the periphyton guidelines to streams in the Te Waihora catchment is of limited value, because nitrate concentrations in the Te Waihora catchment are in the order of 10 times those used in the biomass model. As such, model assumptions regarding nutrient and periphyton relationships would be applied well outside the calibration range used to develop the models, meaning that the predictive ability of the models is limited and questionable.

16. Notwithstanding the limitations to modelling periphyton biomass in Te Waihora tributaries I have expressed above, I understand that Bidwell & Norton (2009) have expressed a desire to see such modelling undertaken. Therefore, in the following two sections I use the equations in the periphyton guidelines to predict effects of nutrient increases on compliance with PNRRP guidelines, trophic state and periphyton biomass in the lowland tributaries of Te Waihora.

Predicted Effects of CPW on PNRRP Objectives for Lowland Streams

17. I have attached to my evidence plots (Figures 1 to 6) showing nitrate plus nitrite nitrogen (NOx-N) and dissolved reactive phosphorus (DRP) concentrations from the seven tributaries of Te Waihora downgradient and potentially affected by the CPW scheme that have a good monitoring record. As described earlier, there is monthly data and most sites have at least 150 samples taken over at least 12 years (the exception being Boggy Creek which only has data since 2003). I have overlaid each plot with the MfE guidelines for the prevention of nuisance algal growths (Biggs 2000), using the same assumptions regarding flood disturbance as those used in the most recent regional water quality summary report of Hayward et al. (2009). Thus, I have assumed an average accrual period of 100 days for spring-fed tributaries and 33 days for the Selwyn River.

18. I note that the periphyton guidelines refer to DIN, which comprises nitrate, nitrite and ammoniacal forms of nitrogen. Nitrate toxicity guidelines refer solely to nitrate nitrogen. However, the majority of ECan water quality data is reported only as NOx-N, which comprises nitrate and nitrite. I have examined the relative contribution of ammoniacal, nitrate and nitrite forms of nitrogen to DIN for many lowland streams in Canterbury. I have consistently found that nitrate is the predominant form of inorganic nitrogen (i.e., typically >90%). As such, I consider it is valid to use the terms DIN, NOx-N and nitrate interchangeably in relation to this particular assessment, and do so through my evidence.

19. The MfE periphyton guidelines I have used relate to the PNRRP Objective WQL1 outcome of streambed coverage with filamentous algae (>2 cm) not exceeding 30% (i.e., equivalent to 120 mg/m² of chlorophyll *a*). I note that while this results in a lower chlorophyll *a* threshold than the objective of <60% bed coverage with thick mats (200 mg/m² of chlorophyll *a*), I have used the lower number for two reasons. First, because there is no hierarchy given to the WQL1 objectives, I have chosen the more stringent (lower) guideline. Second, filamentous algae tends to dominate over thick mats in the Te Waihora tributaries, due to the general lack of suitable stony substrates to colonise and the dominance of macrophytes (which long filamentous algae can adhere to, but thick mats can not).

20. The attached plots (Figures 1 to 6) clearly show that, based on NOx-N concentrations, the periphyton guideline is currently exceeded 100% of the time in all of the rivers, with the exception of the Irwell River, where it is exceeded 99% of the time. Similarly, based on DRP concentrations, the periphyton guideline is exceeded over 98% of the time in all rivers, with the exception of the Selwyn River, where it is exceeded 90% of the time.

21. Figures 7 and 8 show that when the extensive ECan water quality monitoring dataset is compared with the predictive periphyton model given in the periphyton guidelines, it is clear that DIN concentrations in the Te Waihora tributaries are almost always exceeding limits required to meet Objective WQL1of the PNRRP. If the guidelines are exceeded 100% of the time now, adding further nitrate will not change this. The average DIN concentrations required to meet the WQL1 periphyton objectives (for spring-fed streams with 100 day accrual lengths) is <0.01 g/m³ and present-day mean DIN concentrations are at least 100 times this value.

22. Dissolved reactive phosphorus concentrations exceed periphyton guidelines for most of the time in the Te Waihora tributaries (Figure 8), but approximately 10% of the observations in the Selwyn River show DRP concentrations below the limit required to meet Objective WQL1. Thus, based on current monitoring data, there is the potential for further exceedances of the WQL1 standard for 10% of the observations in the Selwyn River.

23. A concern expressed by Bidwell & Norton (2009) is that CPW have not effectively assessed phosphorus loss from the CPW area. However, in his supplementary evidence, Mr Tipler has explained in detail why phosphorus loss from the CPW area was not quantified, highlighting the fact that the major source of phosphorus is from surface runoff and that this is relatively easy to mitigate on flatter land (whilst acknowledging that mitigation will not necessarily be 100% successful).

24. Based on existing DRP and DIN data in comparison to predictive models in the periphyton guidelines, I conclude that all of the rivers would not currently comply with Objective WQL1 for over 95% of the time and CPW will not change this. There is a small risk that CPW could result in reduced compliance with Objective WQL1, if DRP concentrations in the Selwyn River were to increase. In my opinion, this is a small risk, as CPW is unlikely to significantly increase

DRP concentrations in lowland streams, as outlined in Mr Tipler's supplementary evidence.

Effects on the Trophic State of Lowland Streams

25. The periphyton guideline formulae for assessing nutrient impacts on periphyton biomass can be used to assess the trophic state of a waterway. The periphyton guideline suggests that the oligotrophic-mesotrophic boundary and the mesotrophic-eutrophic boundary equate to 120 and 200 mg/m² of chlorophyll *a*, respectively (Biggs 2000). Tables 1 and 2 attached to my evidence show the current predicted periphyton biomass (chlorophyll *a*) for Te Waihora tributaries, based on the empirical formulae given in Biggs (2000), assuming either N or P is limiting. I will note here that the actual biomass predicted by the formulae may vary greatly compared to what is actually observed in the field, due to the influence of other physical and biological processes. As such, I consider that the relative size of predicted chlorophyll *a* concentrations is of more interest than absolute numbers.

26. Table 1 attached shows that if nitrogen is the limiting nutrient in the tributaries modelled, maximum chlorophyll *a* concentrations are predicted to be in the range of around 1,800 to 6,100 mg/m², which is around 9 to 30 times the eutrophic limit of 200 mg/m². Table 2 attached shows that if phosphorus is the limiting nutrient in these streams, the periphyton model predicts chlorophyll *a* concentrations in the range of 345 to 1,600 mg/m², which is around 1.5 to 8 times the eutrophic limit.

27. In my opinion, the modelled data in Tables 1 and 2 clearly show that, based on existing nutrient concentrations, all of the lowland tributaries of Te Waihora downgradient of CPW are in a very eutrophic state. This also means that additional nutrients will not result in a shift in trophic state from oligotrophic to eutrophic, because the streams are already eutrophic.

28. Notwithstanding my comments regarding the limited value of modelling nutrient effects on periphyton biomass in stable spring-fed streams with very high nutrient concentrations, I have undertaken this modelling step, to address the concerns raised in the Bidwell & Norton (2009) report. I understand that there is some difference of opinion amongst groundwater experts about whether nitrate concentrations will increase in groundwater and lowland streams and, if they do, by what quantum. In his main brief of evidence, Mr Tipler estimated

groundwater nitrate concentrations would increase by about 1.2 g/m^3, above a median background concentration of 3.7 g/m^3 (i.e., a 30% increase). With the revised scheme, Mr Tipler has in his supplementary evidence predicted groundwater nitrate concentrations would increase by an average of 0.5 g/m^3 above a background concentration of 4.2 g/m^3 (i.e., a 12% increase). Because of the inherent uncertainty involved in groundwater nitrate modelling predictions, and some disagreement between experts as to whether CPW will affect DRP concentrations, I have modelled the effect of NOx-N and DRP increases over a range from 10% to 100% above existing levels.

29. Based on the predictive formulae in the periphyton guidelines (paragraph 9 above), a 10% increase in either NOx-N or DRP concentrations would result in a 5% increase in periphyton biomass in the tributaries modelled (see Tables 1 and 2 attached). A 30% increase in NOx-N or DRP concentrations would result in an average increase in periphyton biomass of 14%. In my opinion, an increase in periphyton biomass in the order of 5 to 14% above existing levels would be barely detectable and I consider it a very small effect. A 50% increase in nutrient concentrations results in periphyton biomass increasing by 23 and 22% for NOx-N and DRP formulae, respectively. A doubling of nutrient concentrations results in periphyton biomass increasing by 42 and 41% for NOx-N and DRP formulae, respectively.

30. Clearly, the periphyton model predicts that increased nutrient concentrations will result in proportionally smaller increases in periphyton biomass; hence a doubling of nutrient concentrations results in less than a 50% increase in periphyton biomass. This is because the relationship between nutrient concentration and periphyton biomass is described by a logarithmic function. Because of this logarithmic relationship, nutrient increases in the order of 10 to 30% (i.e., within the range predicted by CPW) will have only a small effect on periphyton biomass.

31. In summary, I have used the predictive modelling approach to assess effects of CPW on eutrophication in lowland streams, as advocated by Bidwell & Norton (2009) and used recently by GHD (2009) in the upper Waitaki and by Norton et al. (2007) for the Hunter Downs application. In my opinion, the modelling results clearly show that the lowland tributaries of Te Waihora are presently in a highly eutrophic state and therefore that the CPW scheme presents a low risk of shifting their trophic state from oligotrohic to eutrophic. The modelling results

also predict that average nitrate increases in the range predicted by Mr Tipler will result in only a small increase in periphyton biomass above existing levels. I acknowledge that effects will vary from stream to stream, depending on the relative proportion of irrigated land upgradient of each stream, and I have accordingly modelled a range of potential nutrient increases and potential effects. In my opinion, these relatively small potential adverse effects need to be weighed up against the large positive effects of increased flow and aquatic habitat in the Te Waihora tributaries caused by increased drainage from the CPW area.

Revised Nitrate Toxicity Guideline

32. ECan has recently published a review of the ANZECC (2000) nitrate toxicity guideline for aquatic freshwater species, which was undertaken by NIWA (Hickey & Martin 2009). The review concluded by proposing revised nitrate toxicity guidelines suitable for application in Canterbury freshwaters. While there are a range of trigger levels given in the NIWA report, Hickey & Martin (2009) recommend that the revised nitrate guideline value for 95% protection of 1.7 g/m^3 of nitrate-N be used for Canterbury's rivers and lakes. I have overlaid the proposed revised guidelines on the plots of NOx-N concentrations from Te Waihora tributaries attached to this evidence (Figures 1 to 6). The plots show that for most of the Te Waihora tributaries monitored, the trigger level of 1.7 g/m^3 is currently frequently exceeded. If the CPW scheme increases nitrate concentrations in lowland streams downgradient (as it is predicted to do), then there is an increased likelihood of the revised nitrate toxicity trigger levels being exceeded.

33. The histogram in Figure 9 attached shows the percentage of observations that exceed the different toxicity guideline trigger levels for the Te Waihora tributaries. The histograms show that the recommended 1.7 g/m^3 NO_3-N trigger level is currently exceeded >95% of the time in the Halswell River, LII River, Selwyn River, Doyleston Drain, and Harts Creek, and is exceeded 89% of the time in Boggy Creek, 71% of the time in Hanmer Road Drain, and 29% of the time in the Irwell River.

34. My colleague, Principal Environmental Chemist, Dr Mike Fitzpatrick, has undertaken a peer review of ECan's revised nitrate toxicity guidelines. In summary, Dr Fitzpatrick's opinion is that while he picked up some (slight) errors

in NIWA's toxicity recalculation process, he is generally of the opinion that the revised trigger levels are about right for the data they were based on. However, he did point out that the revised nitrate trigger levels are strongly influenced by toxicity data for early life stages of salmonids and therefore the guideline trigger levels are most applicable to trout and salmon streams. For other waterways that do not support salmonid spawning or juvenile rearing, the salmonid data could be removed and the toxicity guidelines revised, so that more site-specific criteria could be used that would likely have higher trigger levels.

35. As I mentioned in my earlier supplementary evidence (dated September 2009), there are a number of Canterbury streams that sustain healthy invertebrate populations and abundant trout populations, despite having very high nitrate concentrations. For example, as discussed in my September 2009 supplementary evidence, streams in the Hinds-Ashburton area have high nitrate concentrations that exceed the revised nitrate toxicity guidelines, yet until very recently, Fish and Game have regularly harvested juvenile brown trout from several of the lowland streams within the Hinds-Ashburton area to stock high country lakes. Fish and Game ceased this practice following the arrival of didymo and the biosecurity risk posed by transferring fish between catchments.

36. Similarly, in a recent trout spawning survey of the Te Waihora catchment Taylor & Good (2006) concluded that, *"An increase in trout redd numbers* [relative to the 1980s] *were recorded from particular fenced and planted reaches of Boggy Creek and the mainstem of Harts Creek. It was encouraging to record the increased utilisation of protected restored reaches for trout spawning, and indicates that waterways in the Ellesmere catchment can be maintained (and even enhanced) for environmental values, while allowing the surrounding land to remain productive from an agricultural perspective."* Although based on limited sampling data, Taylor & Good's (2006) report indicates that streams such as Harts Creek and Boggy Creek may have in fact experienced improved trout spawning activity over the last 20 years, despite having nitrate-N concentrations that far exceed the revised nitrate toxicity guideline. It is for these reasons that I urge caution in the interpretation and application of the Hickey & Martin (2009) toxicity guidelines.

37. The reason I have given these examples of apparently healthy brown trout populations in streams with high nitrate concentrations, is that I am concerned about how the revised nitrate toxicity guideline will be interpreted by decision makers on individual consents, when there is limited field data to support the guidelines. Furthermore, it is my opinion that significant, catchment-wide issues of cumulative water quality effects on lowland streams need to be addressed on a catchment-wide basis, such that both adverse effects and mitigation options are considered and applied throughout the catchment, rather than in the relative isolation of an individual consent application. As I discuss further in paragraphs 53 to 54 below, the draft Canterbury Water Management Strategy indicates that catchment-wide mitigation of nitrate losses could allow for increased landuse development and irrigation, whilst maintaining or reducing existing nitrate levels in groundwater and spring-fed lowland streams, depending on the degree of mitigation.

38. In summary, data from lowland tributaries of Te Waihora show that nitrate-N concentrations exceed newly revised nitrate toxicity trigger concentrations. If CPW further increases nitrate-N concentrations in lowland streams, then this will result in the toxicity trigger levels being exceeded more frequently.

39. In my opinion cumulative water quality effects need to be managed at a catchment-scale. CPW have committed to using best management approaches to help minimise nutrient losses. Modelling data from the Canterbury Water Management Strategy suggest that if mitigation measures such as those proposed by CPW were implemented throughout the catchment, including on existing irrigated farms, then nitrate concentrations would not increase, or could in fact be reduced below existing levels, whilst allowing for further irrigation development.

EFFECTS ON TE WAIHORA

Modelling Water Quality Effects

40. A key criticism Bidwell & Norton (2009) made of the CPW effects assessment and technical evidence to date is that there has been no attempt made to quantify effects of the predicted increased nitrate loading to Te Waihora on lake ecology. To address this issue, in this part of my evidence I have evaluated the

effect of increasing nutrient concentrations in Te Waihora on the Trophic Level Index (TLI) for lakes. The TLI of Burns et al. (2000) is a standard index used to evaluate lake health throughout New Zealand. I have used the TLI to illustrate the current trophic status of Te Waihora and to assess whether increasing nutrient concentrations will result in an appreciable shift towards a more eutrophic state.

41. In a recent review of PNRRP water quality objectives and standards, Hayward et al. (2009) recommended that nutrient standards for coastal lakes such as Te Waihora should be set at the mesotrophic/eutrophic threshold, which corresponds to TLI score of 4. Hayward et al. (2009) acknowledged that a TLI score of 4 is low relative to the current state of many coastal lakes (most of which have TLI scores >5), but they considered the objective to be in line with community desires to improve the overall health of coastal lakes. As such the proposed PNRRP objective of a TLI value of 4 represents a "desired future state", rather than a "line in the sand" which shall not be crossed. However, I note that Hayward et al. (2009) offered no indication of whether the objectives were achievable and they provided no clear management direction as to how to how the water quality objectives might be achieved.

42. The TLI is calculated using average concentrations of total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, and Secchi depth (a measure of water clarity). Values for each of these four parameters are converted into individual TLI scores, using regression equations developed by Burns et al. (2000). Of relevance here is the fact that each increase in TLI score equates approximately to a doubling in concentration (or a halving in clarity, in the case of Secchi depth). TLI scores for the four parameters are averaged to give an overall TLI score. However, for naturally turbid coastal lakes, Secchi depth data can be excluded, as it may skew the overall TLI score to a lower value than would be indicated by nutrients and chlorophyll *a* concentrations alone.

43. Figures 10 to 13 attached to my evidence show TN, TP and chlorophyll *a* concentrations at the four ECan monitoring sites on Te Waihora in relation to TLI categories. The plots show that TLI scores based on nutrient concentrations and Chlorophyll *a* concentrations are indicative of hypertrophic conditions (i.e., TLI score >6) at all four monitoring sites. Figure 14 attached shows that TP and chlorophyll *a* concentrations exceed the hypertrophic

threshold >95% of the time and TN concentrations exceed the hypertrophic threshold >80% of the time and the supertrophic threshold >95% of the time.

44. Figures 15 and 16 show mean annual TLI scores, with and without Secchi depth values. The plots clearly show that the four monitoring sites follow a consistent pattern of TLI scores >6; indicative of hypertrophic conditions. The plots also show that excluding Secchi depth values slightly reduces (i.e., improves) TLI scores, but that the TLI scores still remain in the hypertrophic category.

45. TLI scores for Te Waihora are currently >6 and as such well exceed the proposed PNRRP objective of Hayward et al. (2009) of a TLI score of 4 for coastal lakes. The high TLI score of Te Waihora reflects its highly nutrient-enriched state and its high phytoplankton biomass.

46. To investigate the effect of increasing nutrient concentrations on lake health, I took the combined average TP, TN and chlorophyll *a* concentrations for all four Te Waihora monitoring sites and increased each of them by 10%, 30%, 50% and 100%. The result was that a 10, 30, 50, and 100% increase in each of the three parameters increased the existing mean TLI score from 7.0 to 7.1, 7.3, 7.5 and 7.8, respectively. Thus, substantial increases in nutrient concentrations and phytoplankton biomass result in relatively small incremental increases in TLI scores, and even a doubling of nutrient concentrations would result in an increase in TLI score of <1 (i.e., within a single TLI category, acknowledging that categories >6 are not formally named).

47. I understand from Mr Tipler's supplementary evidence that the CPW scheme could increase groundwater nitrate concentrations by around 12% above current levels. For the purposes of this assessment, I have assumed groundwater and lowland stream nitrate concentrations are the same and have assumed that lowland streams are the primary source of nitrate to the lake. Based on this desktop assessment, and if other freshwater sources to the lake are ignored, then CPW would result in a relatively small, albeit incremental, increase in TLI score from 7.0 to about 7.2, but this would not result in a significant shift in trophic state (i.e., a TLI increase of >1).

48. The Hunter Downs water quality assessment of Norton et al. (2007) predicted that a doubling of nitrogen concentrations in Wainono Lagoon would at worst case result in a 50% increase in phytoplankton biomass. It is worthwhile noting

that summer average chlorophyll *a* concentrations in Wainono Lagoon were 14 mg/m^3; indicative of supertrophic conditions (compared with mean chlorophyll *a* concentrations in Te Waihora of 98 mg/m^3). Also, mean Secchi depth values for Wainono Lagoon were 0.2 m, compared to an average of around 0.1 m for Te Waihora. These data indicate that Wainono Lagoon is more sensitive to nutrient increases than Te Waihora, due to it being twice as clear (meaning light could penetrate deeper and stimulate algal production) and having lower nutrient concentrations.

49. Of relevance here, in the Hunter Downs assessment, Norton et al. (2007) concluded that *"Overall, despite the clear prediction for increased algal biomass in response to increased nutrients under the HDI Scheme, it seems very likely that the temporal variability and the large range in current nutrient concentrations, combined with the dynamic nature of water level fluctuations, variable salinity and wind mixing, would complicate measurement of the magnitude of algal biomass increase against the existing situation. It is quite possible that a casual observer would not immediately notice such an increase and it is likely that scientific measurements over several years would be needed to quantify the difference."* In my opinion, a similar conclusion could be made for Te Waihora.

50. It is worth pointing out here that for TLI scores in Te Waihora to reach the proposed PNRRP objective for a TLI threshold of 4 (i.e., the mesotrophic/eutrophic boundary), existing mean TN concentrations would need to drop from 2,200 to 337 mg/m^3 and TP would need to drop from 250 to 20 mg/m^3. This corresponds to a reduction in TN concentrations to 15% of current levels and a reduction in TP concentrations to 8% of their current levels. In my opinion, nutrient reductions in the magnitude required to reach the desired TLI score of 4 would require a radical change to the current lake management, including reduced nutrient loading from the entire catchment and possibly also more frequent lake openings, or a permanent lake opening.

MITIGATING WATER QUALITY EFFECTS

Nutrient Management

51. Central Plains Water Ltd have committed to minimising the loss of nutrients from CPW farms, via the Sustainability Protocol and the implementation of best land management practices (BMPs) via individual Farm Plans. Bidwell & Norton (2009) note that BMPs do not completely prevent the loss of nutrients to surface waters and they suggest that BMPs may achieve nutrient retention rates in the order of less than 50% (paragraph 26). I agree that BMPs are not 100% effective and therefore that even with the implementation of best land management practices in the CPW irrigation area, there will still be some loss of nitrate to groundwater and lowland streams.

52. I am strongly of the opinion that implementation of BMPs in the Te Waihora catchment and elsewhere in Canterbury should occur at the catchment scale, rather than on the scale of an individual consent, so that both new and existing irrigators contribute to improved water quality outcomes. This is because it is my opinion that the value of implementing BMPs in only a fraction of the catchment (e.g., the CPW irrigation area) is reduced when the majority of other landowners in the catchment are not also required to adopt BMPs.

53. The recently published draft Canterbury Water Management Strategy sets priorities for managing future irrigation and environmental protection for the Canterbury region. Whilst in draft form, the Strategy sets the tone for future water management in the region and it has the buy-in of all the mayors in Canterbury and the CEO of the regional council. Of relevance to CPW, the Strategy has set goals for nutrient management at the catchment level, including reduced nitrate loadings to groundwater and spring-fed lowland streams.

54. In my opinion, the Canterbury Water Management Strategy provides some assurance that landuse intensification, such as that proposed by CPW, can continue in Canterbury, whilst maintaining and improving water quality outcomes, provided that new and existing irrigators implement BMPs.

Mitigating Effects on Te Waihora

55. Based on the evidence I have heard to date through this hearing, the greatest concern in relation to nutrient effects for Ngai Tahu, the Department of

Conservation and other submitters is effects on Te Waihora. The identified concerns are understandable, given it is clear that Te Waihora is in a very eutrophic state and that as such, the lake management goals of Ngai Tahu will be difficult to meet, irrespective of whether or not the CPW scheme proceeds. Implementation of BMPs are the most effective way of minimising effects of landuse intensification on lowland streams and Te Waihora. However, I acknowledge that there remains some uncertainty as to how effective BMPs will be in reducing nutrient losses.

56. In order to provide some tangible, positive environmental outcomes, CPW are proposing the creation of an environmental fund for ecological enhancement projects, including in and around Te Waihora. For Te Waihora, the environmental fund would be to support projects directly aimed at improving habitat quality and biodiversity values of the lake. Environmental projects eligible for funding could include: control of grey willow and crack willow along the lake shore; riparian planting along tributary streams; detailed lake monitoring and modelling; and investigating the feasibility of constructing a permanent lake opening.

57. I understand from Mr Bob Penter (acting for CPW) that CPW representatives have attempted to meet with Ngai Tahu representatives to discuss potential concerns and mitigation options for Te Waihora leading up to the reconvened hearing. Whilst a formal meeting has not yet been held, I understand from Mr Penter that there is a willingness by both Ngai Tahu and CPWL to further progress this matter, particularly in relation to developing a mitigation package for Te Waihora.

SUMMARY

58. In this evidence I have provided a quantitative assessment of effects in response to the opinions of Bidwell & Norton (2009) that such an assessment was required in order to properly assess environmental effects of the CPW scheme. My key findings are as follows:

Compliance with PNRRP Objectives

59. Based on existing DRP and DIN data in comparison to predictive models in the periphyton guidelines (Biggs 2000), I conclude that all of the lowland rivers

would not currently comply with Objective WQL1 for over 95% of the time and CPW will not change this. There is a small risk that CPW could result in reduced compliance with Objective WQL1, if DRP concentrations in the Selwyn River were to increase. In my opinion, this is a small risk, as CPW is unlikely to significantly increase DRP concentrations in lowland streams, as outlined in Mr Tipler's supplementary evidence.

Trophic State of Lowland Streams

60. Based on existing nutrient concentrations, all of the lowland tributaries of Te Waihora downgradient of the CPW scheme area are in a very eutrophic state. Any additional nutrients from CPW will therefore not result in a shift in trophic state from oligotrophic to eutrophic, because the streams are already eutrophic.

61. Modelling results also predict that average nitrate increases in the range predicted by Mr Tipler in his supplementary evidence (i.e., an increase of 0.5 g/m^3 of nitrate-N) would result in a small increase in periphyton biomass above existing levels (around 5%). However, this would be based on the premise that nitrogen is a limiting nutrient in CPW tributary streams. In my opinion, nitrogen limitation is very unlikely, given the very high existing nitrate-N concentrations.

Nitrate Toxicity

62. NIWA have very recently revised the ANZECC trigger levels for nitrate toxicity. Data from lowland tributaries of Te Waihora show that nitrate-N concentrations currently exceed the newly revised nitrate toxicity trigger levels on a frequent basis (e.g., >95% in the Selwyn River). If CPW further increases nitrate-N concentrations in lowland streams, then this will result in the toxicity trigger levels being exceeded more frequently.

63. I have expressed caution when interpreting the significance of the newly revised trigger levels, given examples of apparently healthy invertebrate and brown trout populations in streams with high nitrate concentrations. I have also stated that the only way to reduce nitrate concentrations in lowland streams is to implement BMP mitigation measures such as those proposed by CPW throughout the catchment, including on existing irrigated farms.

Effects on Te Waihora

64. I assessed the current trophic state of Te Waihora using the TLI of Burns et al. (2000). Average TLI scores for all four lake monitoring sites are currently >6, indicating hypertrophic conditions (i.e., very eutrophic). If nitrogen concentrations in the lake increased by 12% (i.e., the same increase CPW is predicted to have on groundwater), then the average TLI for the lake is predicted to increase from 7.0 to 7.2. Such an increase is not considered a significant shift in trophic state (i.e., a TLI increase of >1).

65. Hayward et al. (2009) proposed an PNRRP objective for coastal lakes for a mean TLI score of 4. ECan monitoring data indicates that to achieve a TLI score of 4, TN concentrations would need to be reduced to 15% of current levels and TP concentrations would need to drop to 8% of their current levels.

Mitigation

66. I agree with Bidwell & Norton (2009) that BMPs are not 100% effective at preventing nitrate losses to groundwater. In my opinion, the Canterbury Water Management Strategy provides some assurance that landuse intensification, such as that proposed by CPW, can continue in Canterbury, whilst maintaining and improving water quality outcomes, provided that new and existing irrigators implement BMPs.

67. In addition to implementing BMPs to avoid the loss of nitrate to groundwater, CPW will fund projects aimed at improving habitat quality and biodiversity values in and around Te Waihora.

GP Burrell, 12 October 2009

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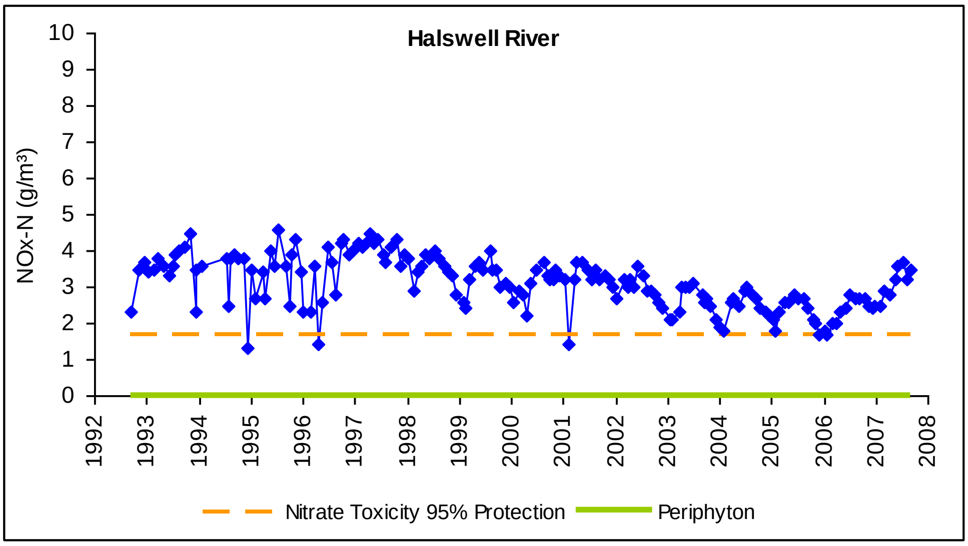
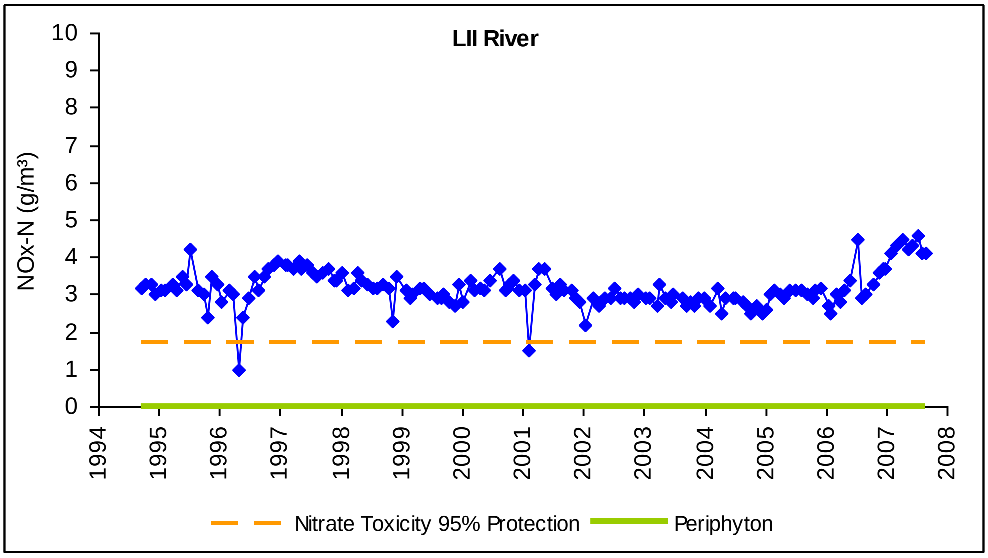
TABLES AND FIGURES





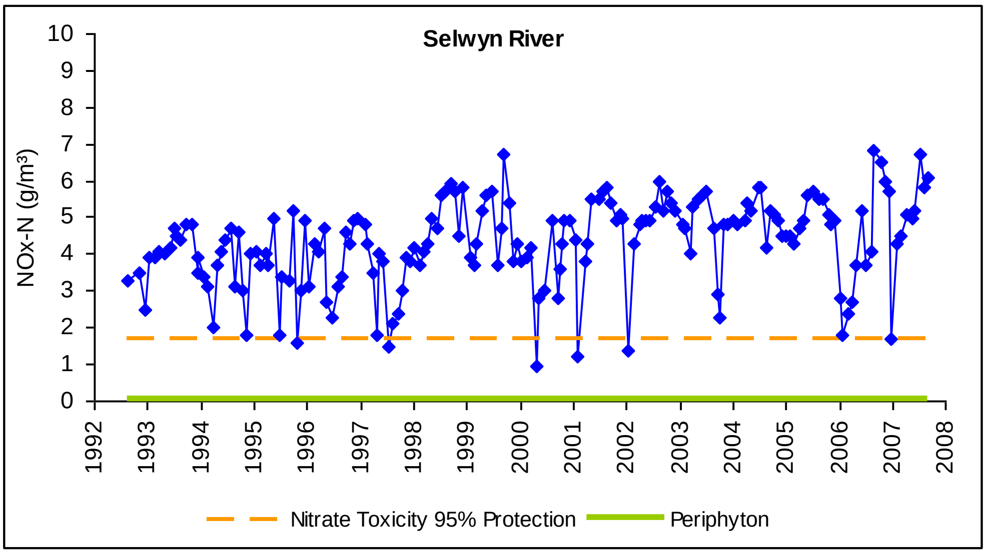


Figure 1: NOx-N concentrations in the Halswell River, LII River and Selwyn River.

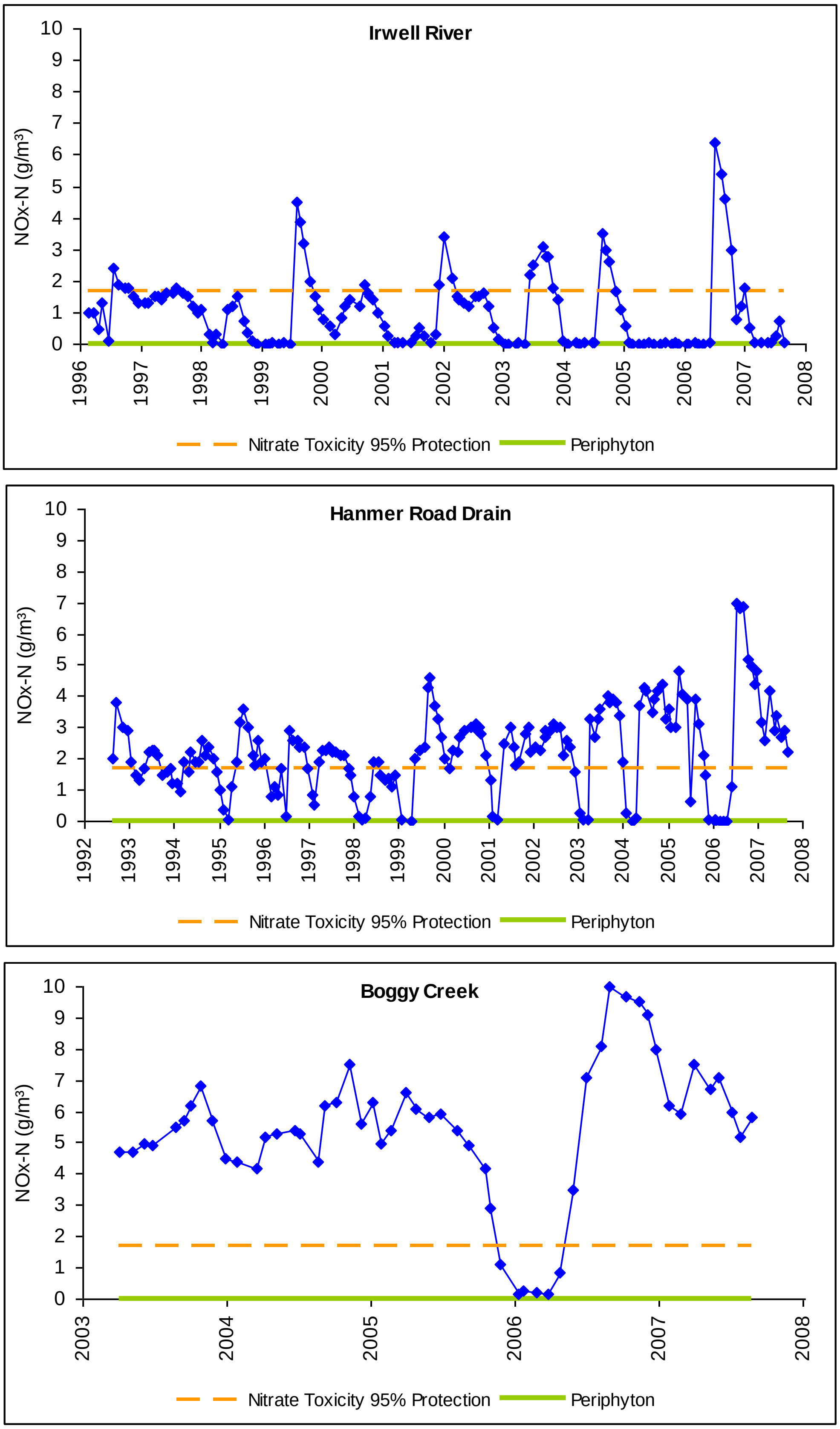


Figure 2: NOx-N concentrations in the Irwell River, Hanmer Road Drain and Boggy Creek.

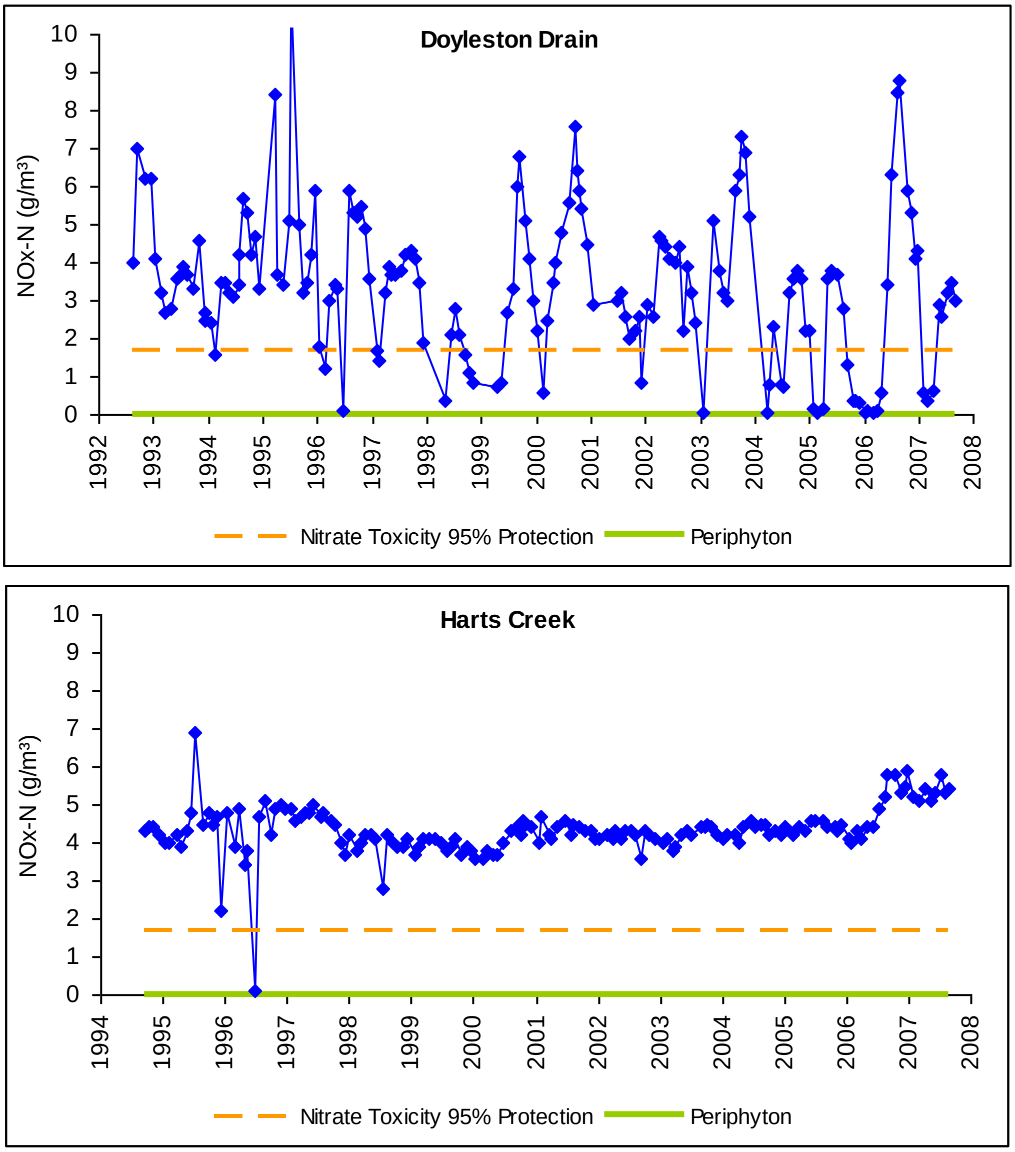


Figure 3: NOx-N concentrations in Doyleston Drain and Harts Creek.

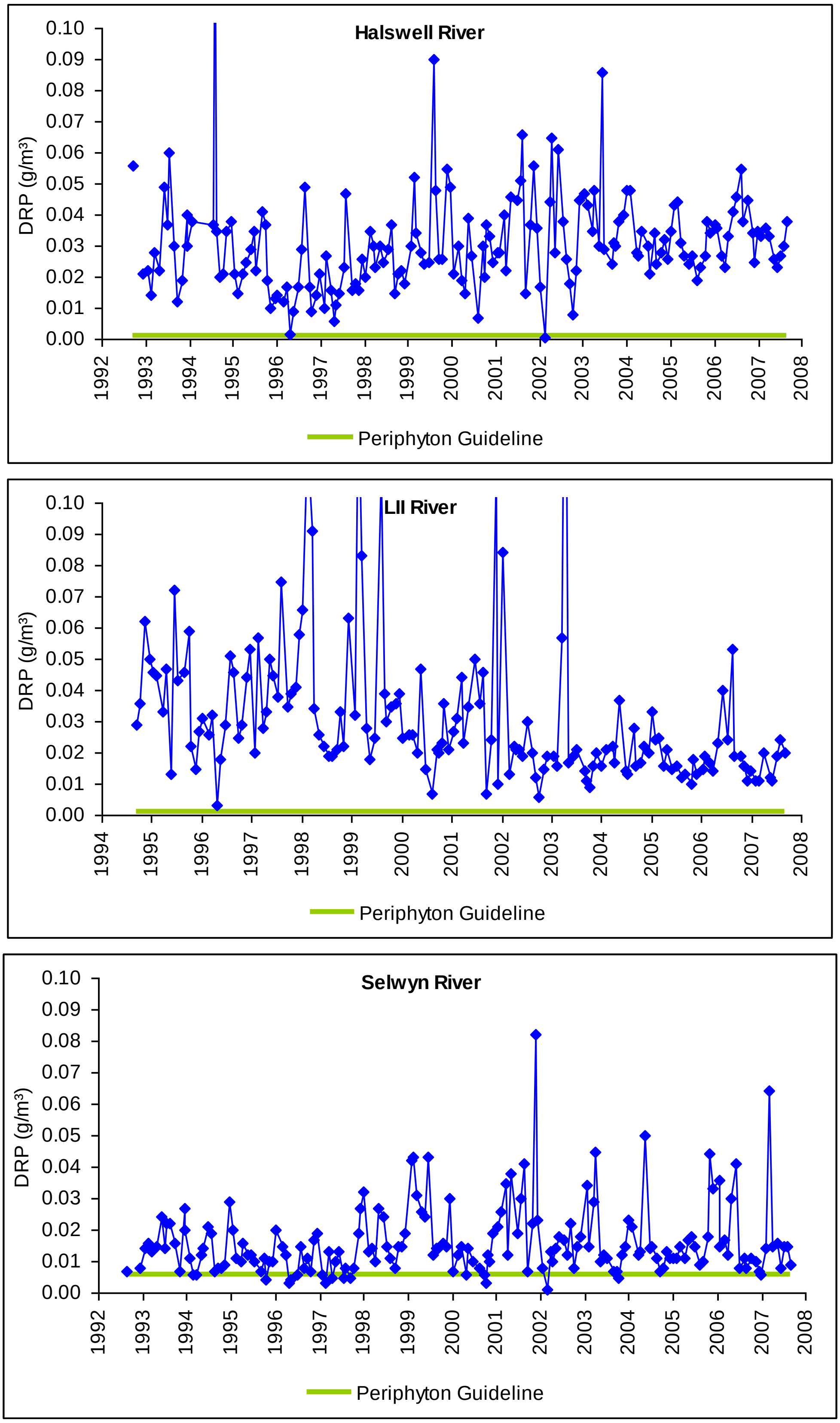


Figure 4: DRP concentrations in the Halswell River, LII River and Selwyn River.

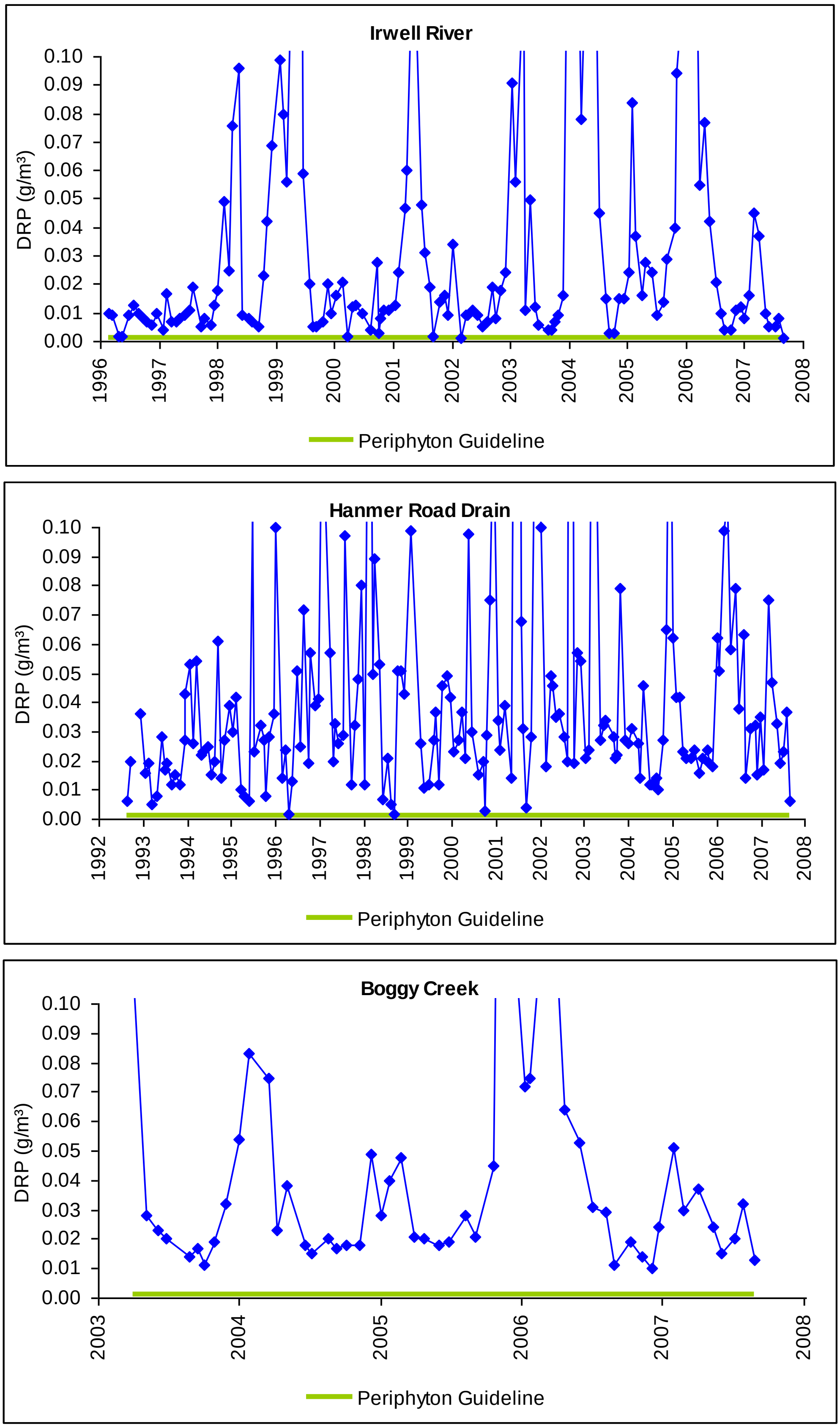
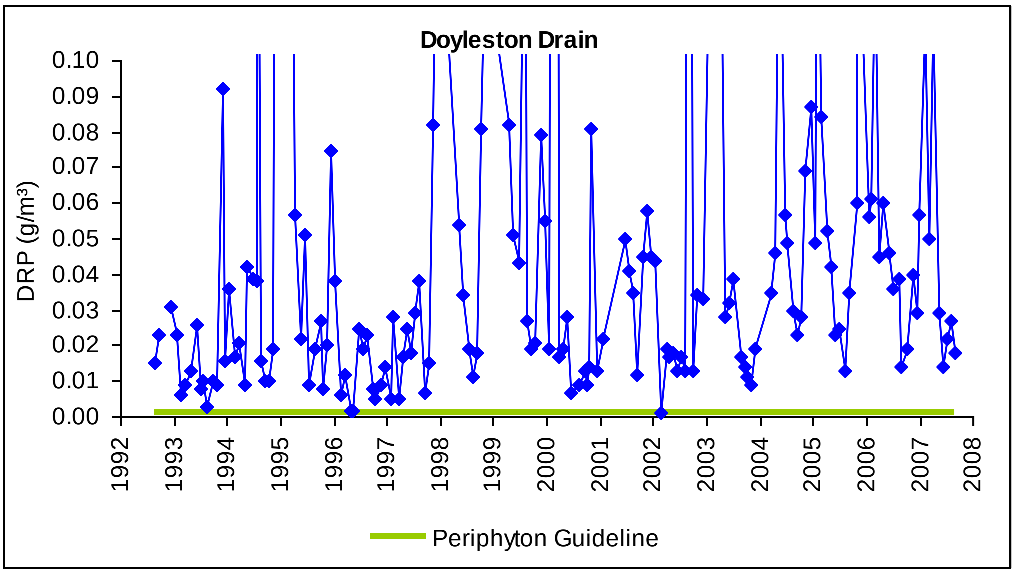


Figure 5: DRP concentrations in the Irwell River, Hanmer Road Drain and Boggy Creek.



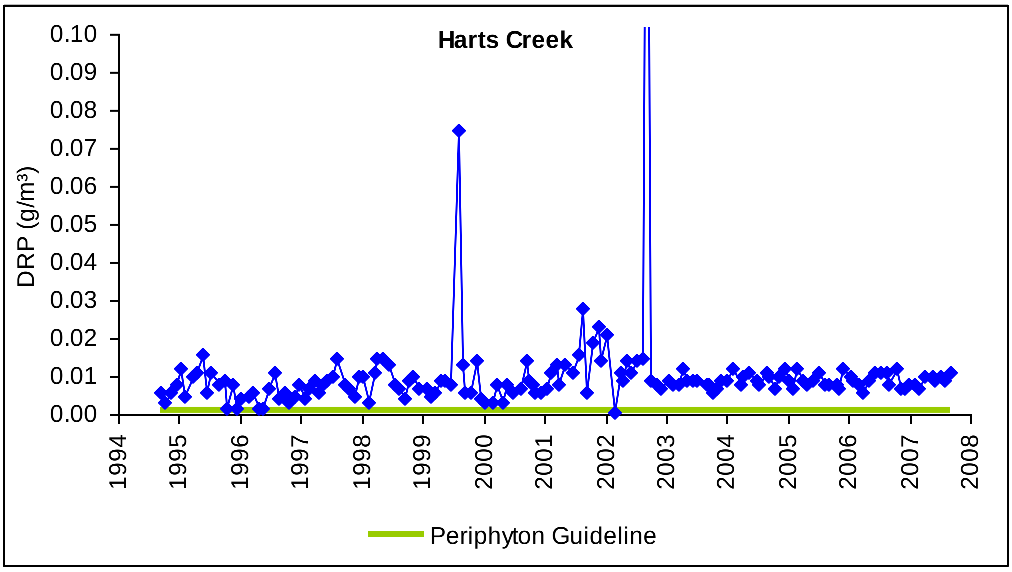


Figure 6: DRP concentrations in Doyleston Drain and Harts Creek.

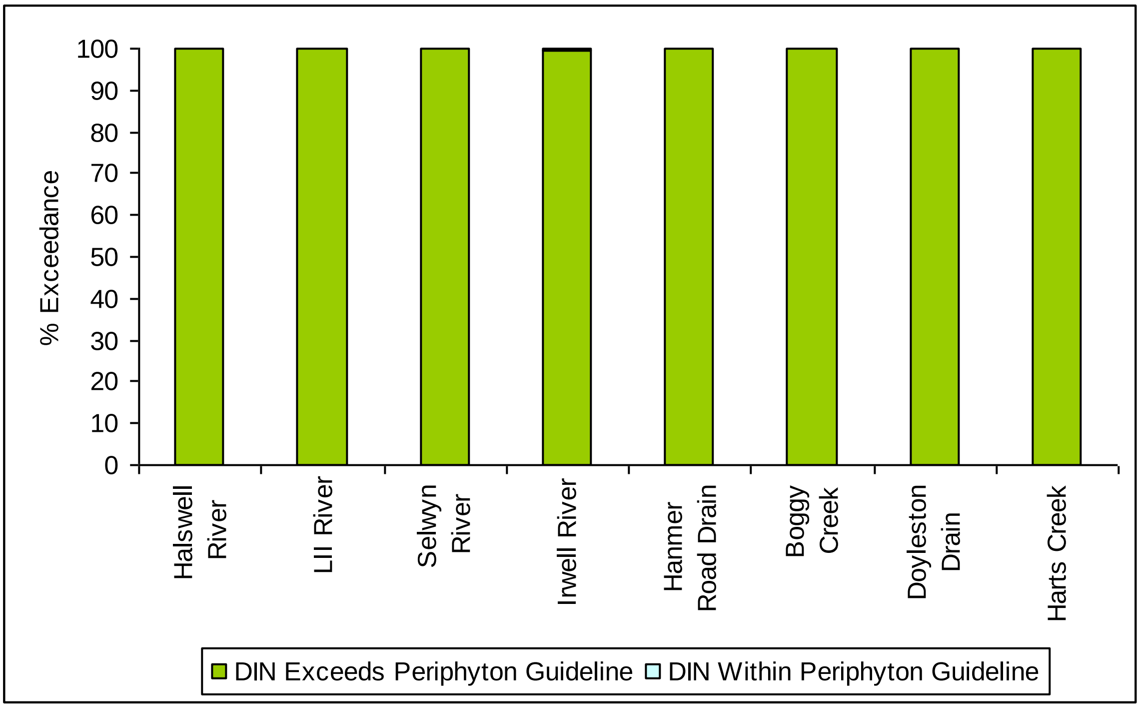


Figure 7: Percentage of exceedance of DIN periphyton guideline for biodiversity and amenity (Biggs 2000).

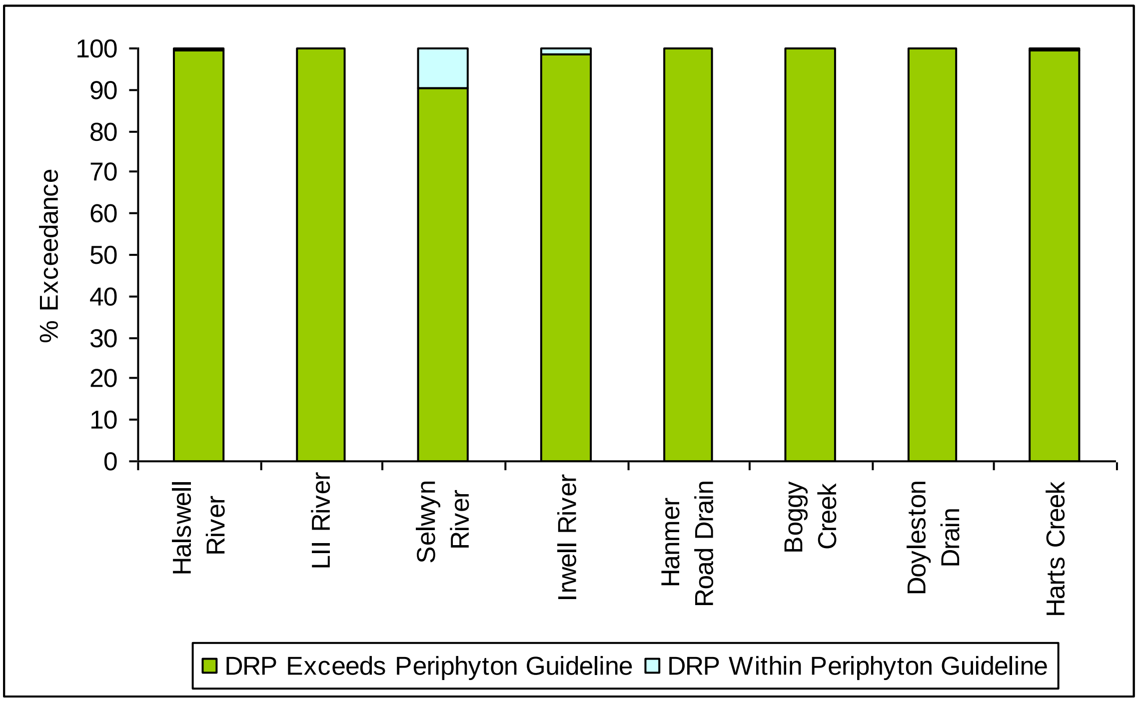


Figure 8: Percentage of exceedance of DRP periphyton guideline for biodiversity and amenity (Biggs 2000).

Table 1: Predicted Chlorophyll *a* concentrations in lowland streams, based on existing and increased NOx-N concentrations calculated using the periphyton guideline formula.

	Existing	**Predicted Chlorophyll *a* biomass (mg/m²)**				
Site	**NOx-N**	**Existing**	**10% NOx-N increase**	**30% NOx-N increase**	**50% NOx-N increase**	**100% NOx-N increase**
Halswell River	3.1	4,659	4,888	5,317	5,715	6,606
LII River	3.2	4,701	4,933	5,366	5,767	6,667
Selwyn River	4.3	1,782	1,870	2,034	2,186	2,527
Irwell River	1.0	2,679	2,811	3,058	3,286	3,799
Hanmer Road Drain	2.3	3,990	4,187	4,554	4,895	5,659
Boggy Creek	5.4	6,138	6,440	7,006	7,529	8,704
Doyleston Drain	3.4	4,877	5,117	5,566	5,983	6,916
Harts Creek	4.3	5,511	5,782	6,290	6,760	7,815

Table 2: Predicted Chlorophyll a concentrations in lowland streams, based on existing and increased DRP concentrations calculated using the periphyton guideline formula.

	Existing	**Predicted Chlorophyll *a* biomass (mg/m²)**				
Site	**DRP**	**Existing**	**10% DRP increase**	**30% DRP increase**	**50% DRP increase**	**100% DRP increase**
Halswell River	0.031	1,333	1,397	1,517	1,628	1,877
LII River	0.032	1,350	1,415	1,537	1,649	1,901
Selwyn River	0.016	345	361	392	421	485
Irwell River	0.038	1,482	1,554	1,687	1,811	2,088
Hanmer Road Drain	0.046	1,620	1,698	1,844	1,979	2,281
Boggy Creek	0.040	1,516	1,589	1,726	1,853	2,136
Doyleston Drain	0.047	1,635	1,714	1,861	1,997	2,302
Harts Creek	0.011	784	822	893	958	1,104

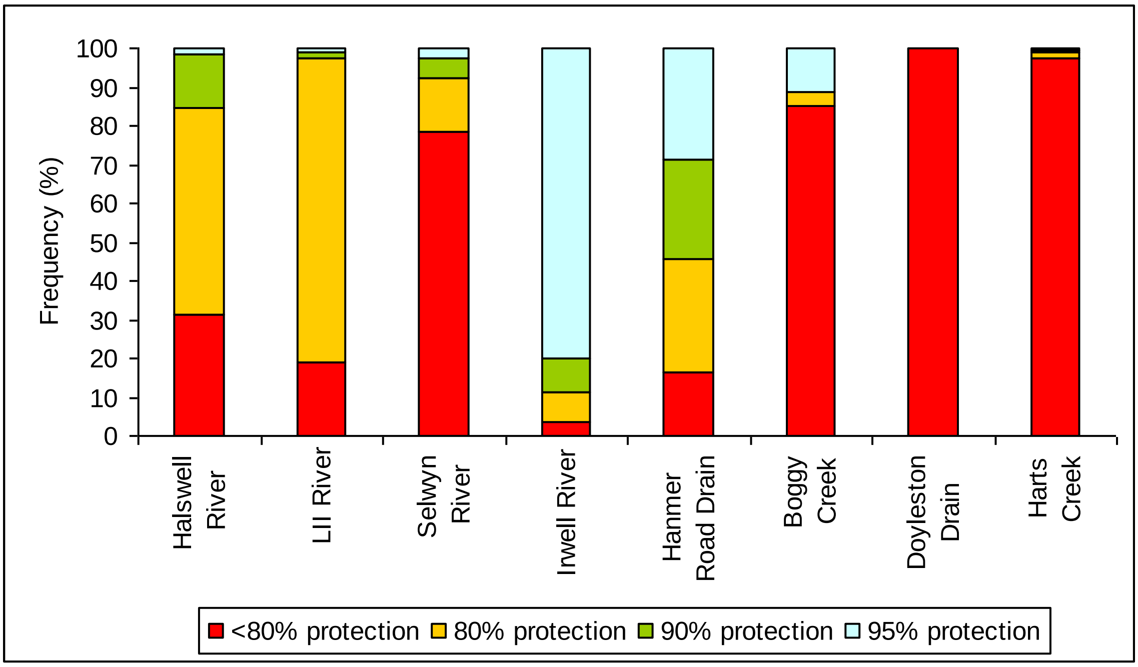


Figure 9: Percentage of exceedances of revised nitrate toxicity trigger levels for chronic highly disturbed systems (ECan 2009). Percentages are based on monthly data from 1992 to 2007, except for Boggy Creek where the record is 2003 to 2007.

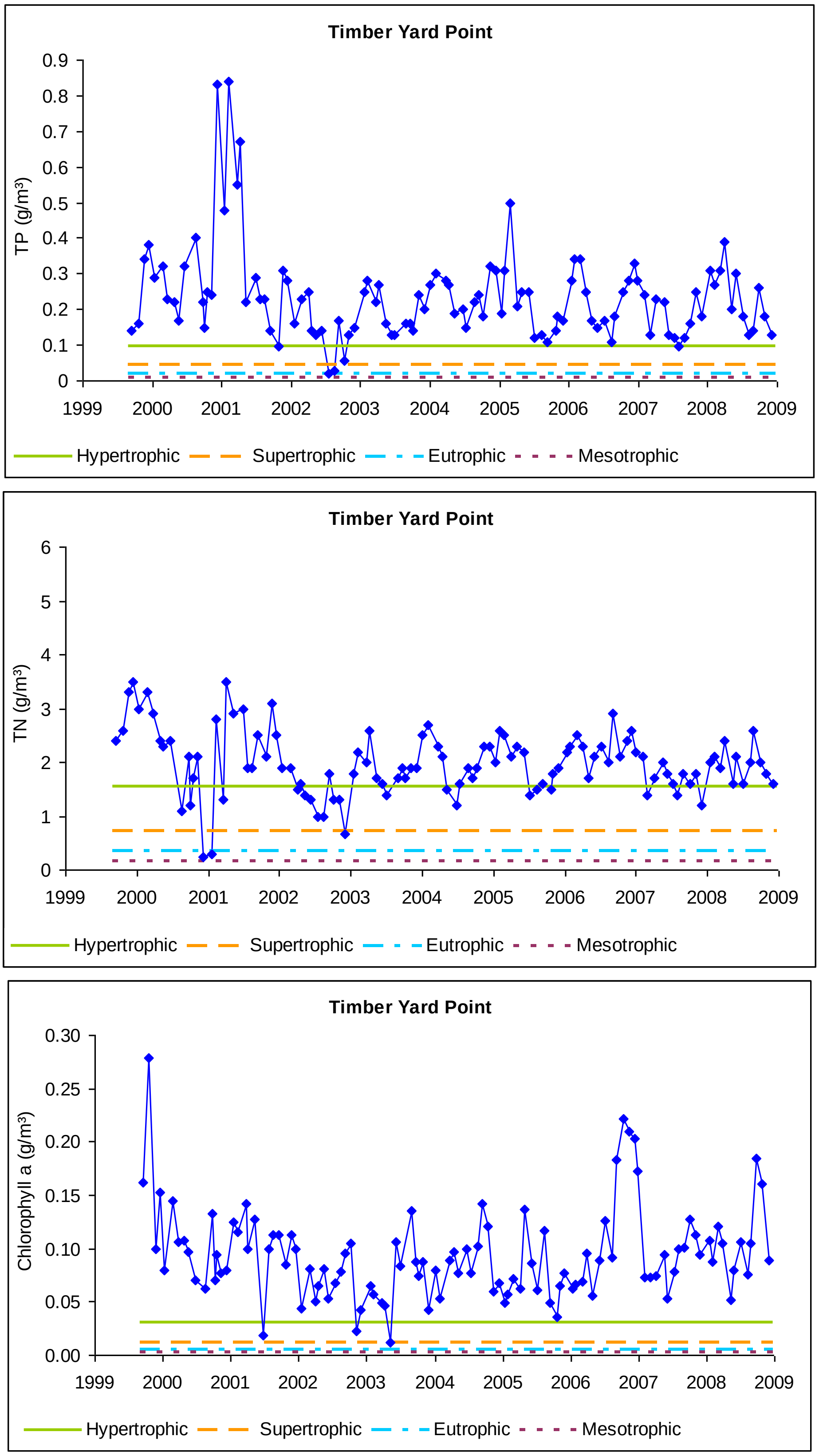


Figure 10: Variation in the trophic state of Te Waihora over time at Timber Yard Point.

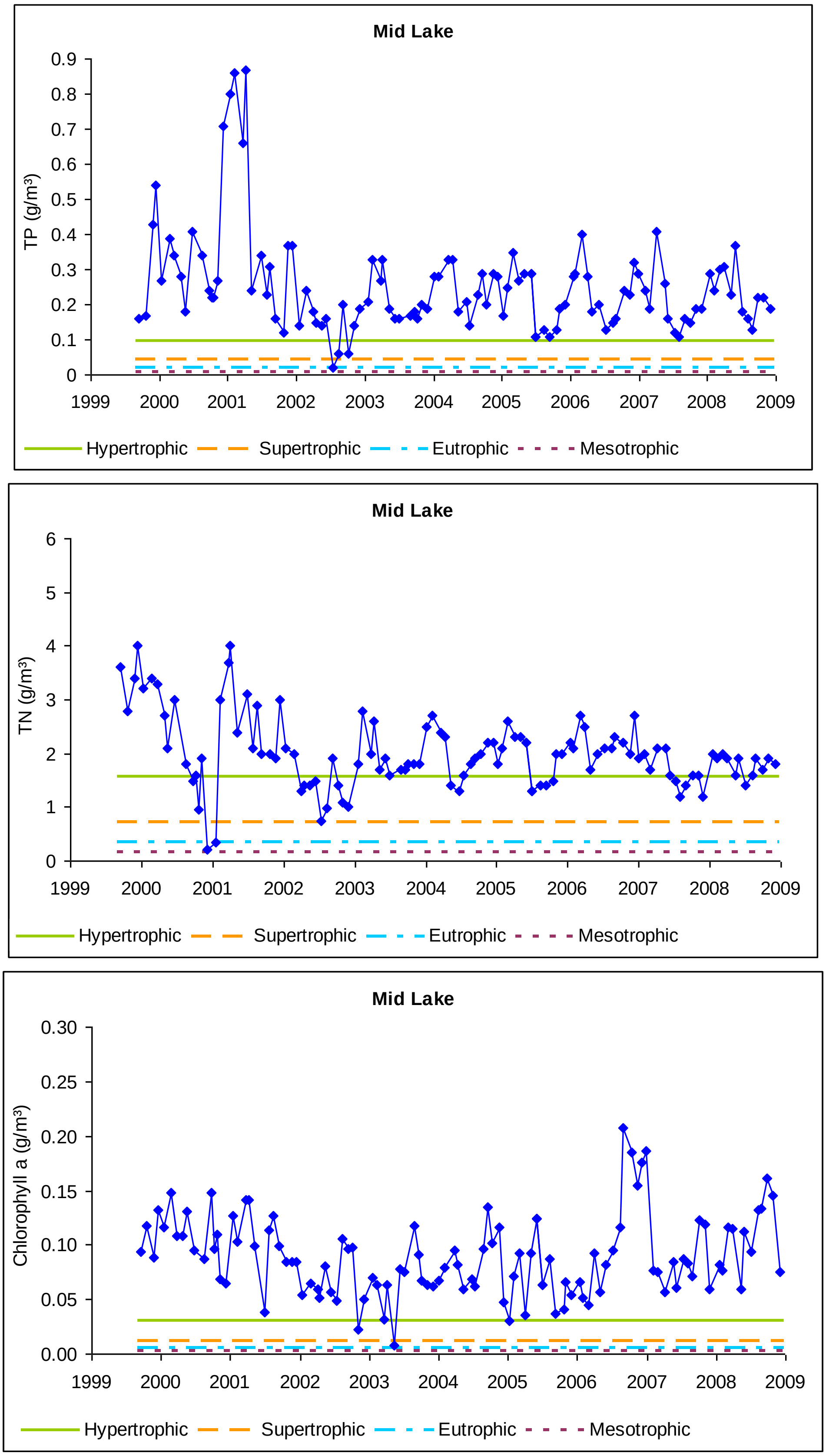


Figure 11: Variation in the trophic state of Te Waihora over time at the Mid Lake monitoring site.

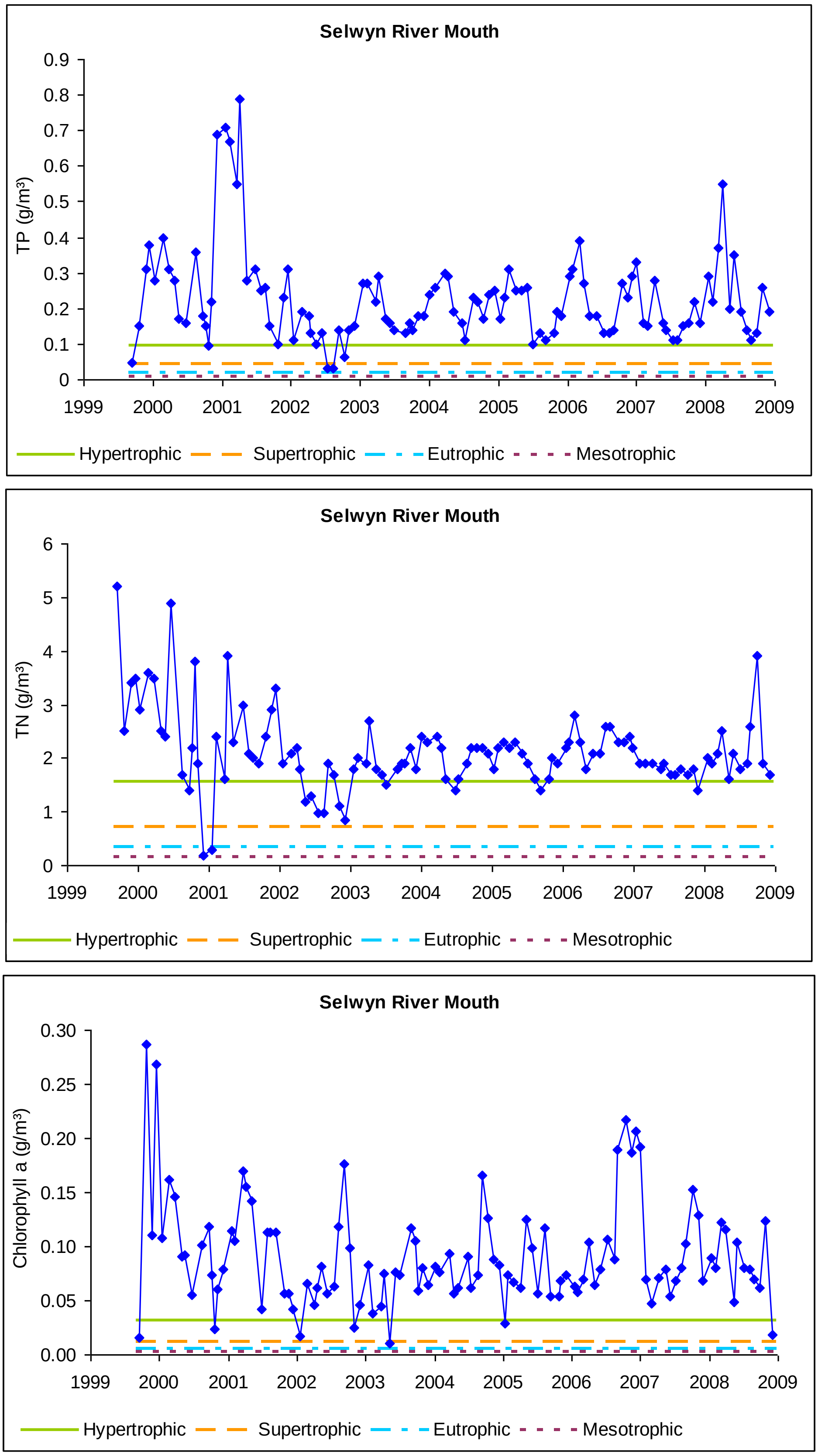


Figure 12: Variation in the trophic state of Te Waihora over time at the Selwyn River mouth.

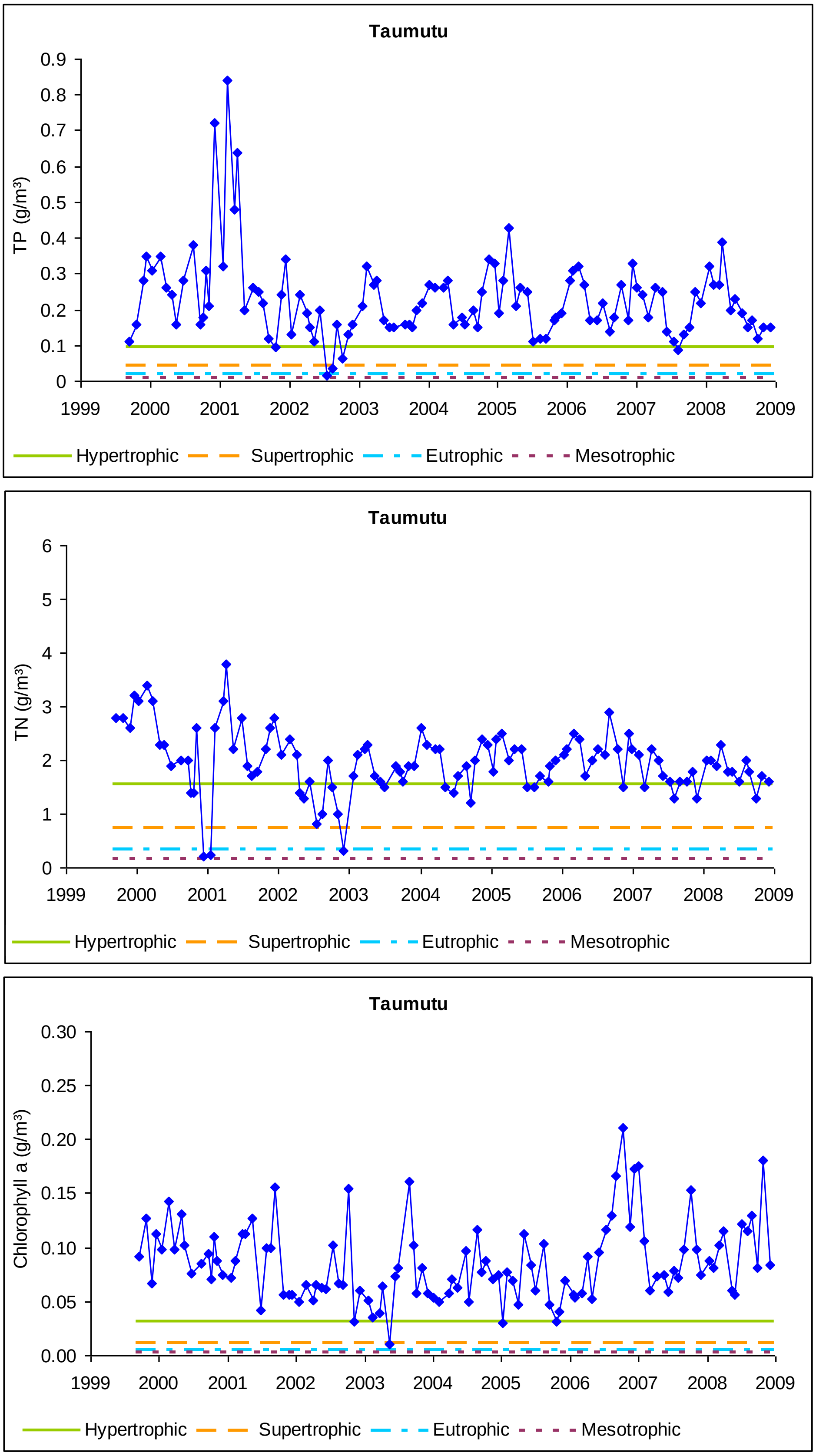
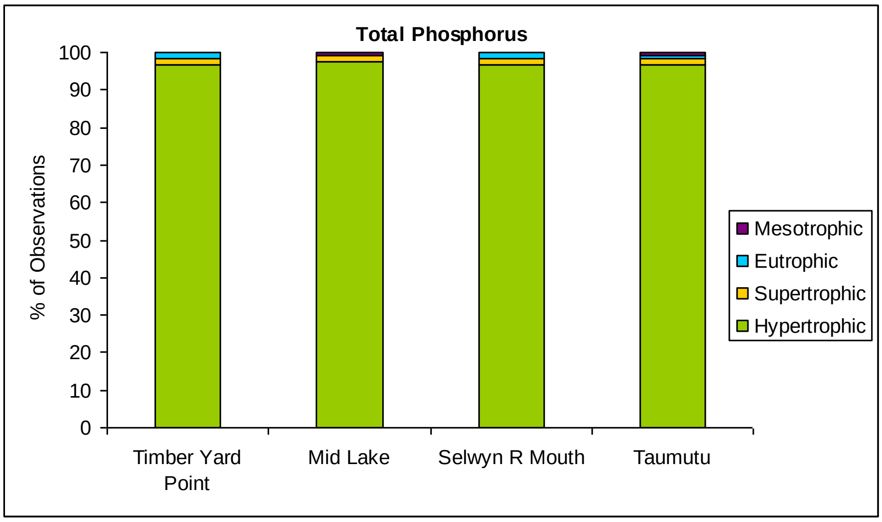
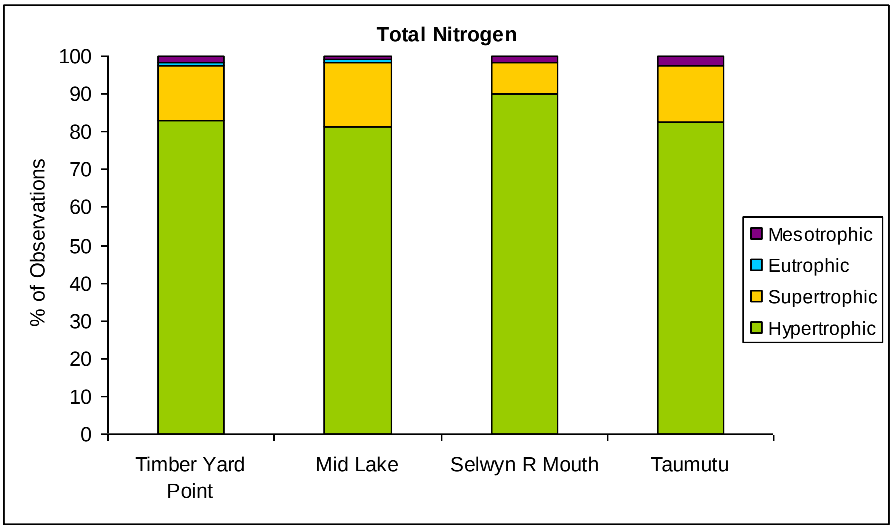


Figure 13: Variation in the trophic state of Te Waihora over time at Taumutu.





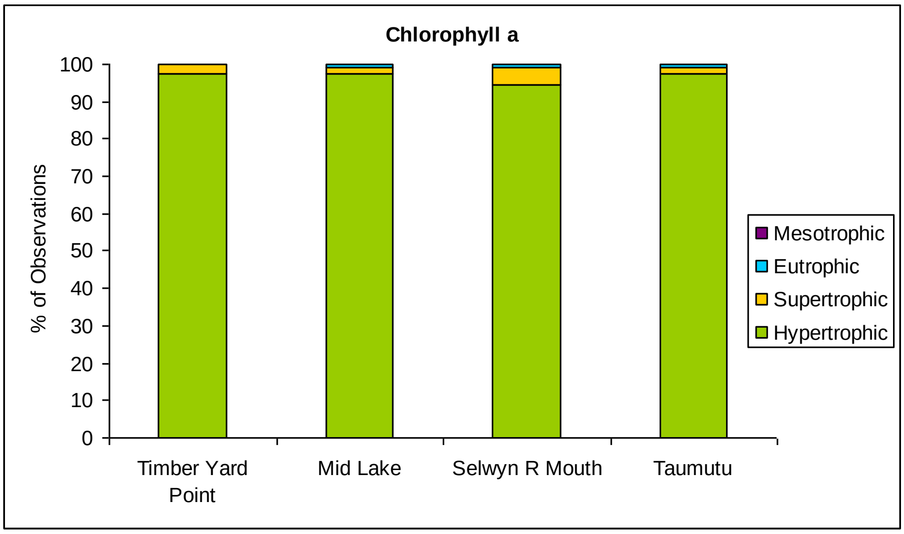


Figure 14: Percentage of total phosphorus, total nitrogen and Chlorophyll *a* measurements falling within the Trophic Level Index categories of Burns et al. (2000) at four sites in Te Waihora. Percentages are based on monthly data from 2000 to 2008.

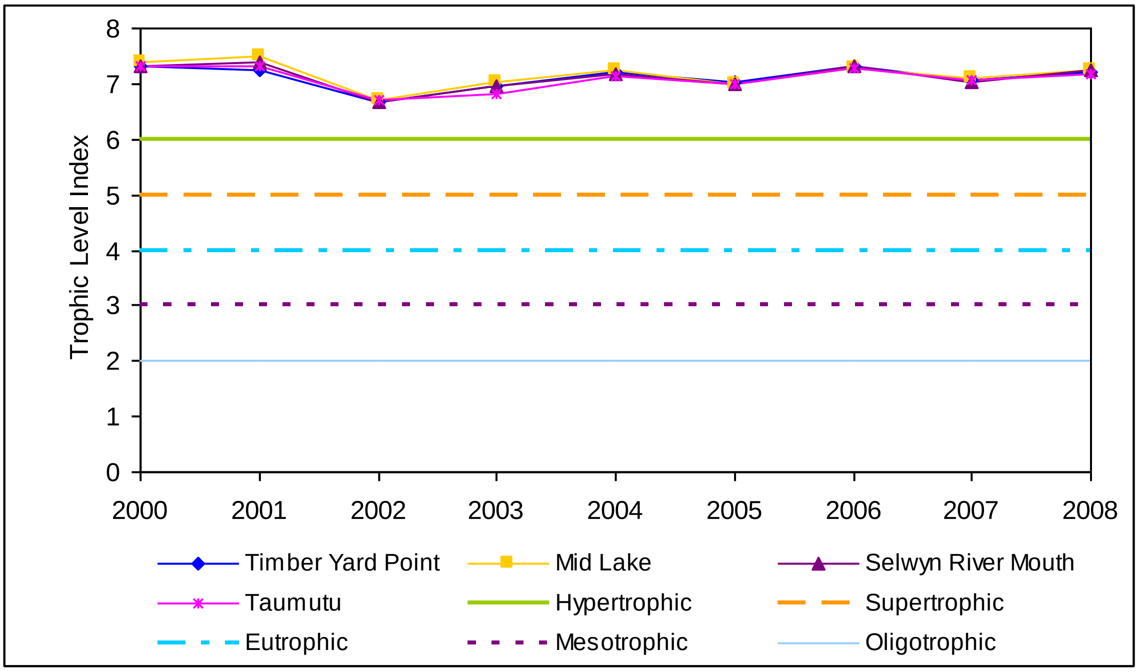


Figure 15: Annual mean Trophic Level Index values from the four Te Waihora monitoring sites from 2000 to 2008.

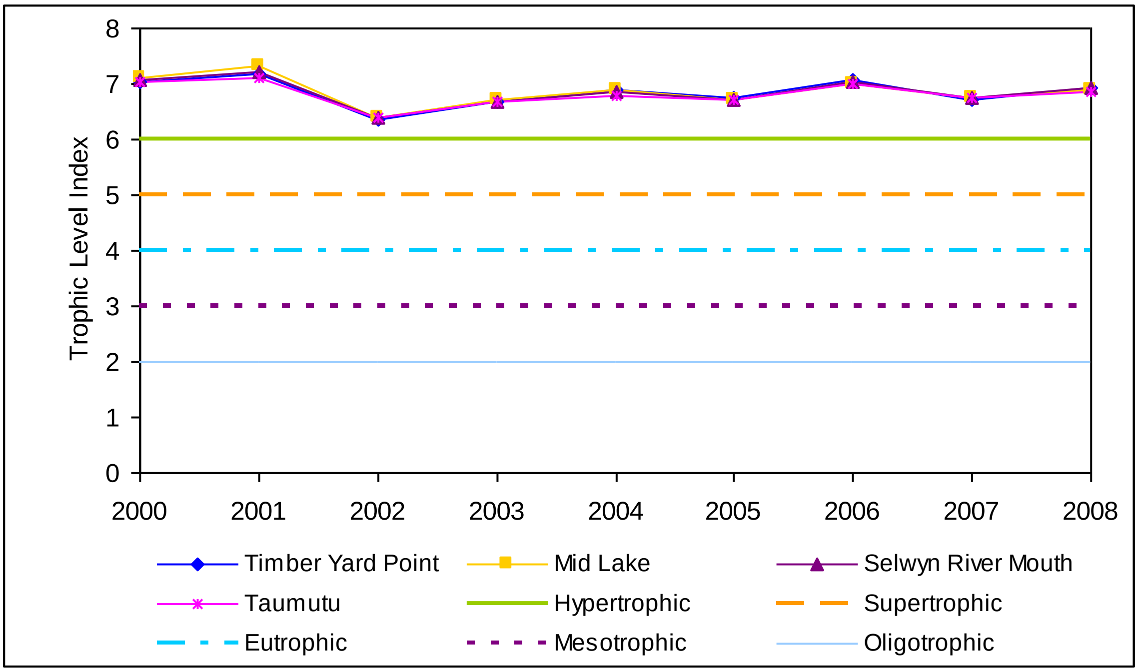


Figure 16: Annual mean Trophic Level Index values from four Te Waihora monitoring sites from 2000 to 2008 (excluding Secchi depth data).

Note:

All data are courtesy of Environment Canterbury. Trophic Level Index values for all plots were calculated using the methods of Burns et al. (2000).

Reference

Burns, N. M.; Bryers, G.; Bowman, E. 2000: Protocol for monitoring trophic levels of New Zealand lakes and reservoirs. Ministry for the Environment, Wellington.