BEFORE THE HEARINGS PANEL

IN THE MATTER	**of hearings on submissions concerning the Proposed One Plan notified by the Manawatu-Wanganui Regional Council**

SECTION 42A REPORT OF DR ROBERT JOHN WILCOCK ON BEHALF OF HORIZONS REGIONAL COUNCIL

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1. INTRODUCTION

My qualifications/experience

1. I have the following qualifications: BSc (Hons) in chemistry, and a PhD in physical chemistry from the University of Canterbury. I am a Fellow of the NZ Institute of Chemistry; a Fellow of the International Union of Pure and Applied Chemistry; a Member of the NZ Freshwater Sciences Society; and a corporate Member of the International Water Association.

2. My present position at NIWA is Principal Scientist and Group Manager, Chemistry and Ecotoxicology.

3. My work experience includes two years as a post-doctoral fellow at Wright State University, Dayton, Ohio, supported by the National Petroleum Research Fund and the National Institute of General Medical Sciences, investigating gas-liquid solubility phenomena in the laboratory of Professor Rubin Battino. I joined the Water Section of the Chemistry Division, DSIR, Wellington, working on analytical chemistry for water analysis, irrigation treatment of effluents and collaborative programmes of water analysis. In 1980 I joined the Hamilton Science Centre, Ministry of Work and Development (MWD) and subsequently became Group Leader of the Rivers Group. I have been at Hamilton since 1980, when MWD was disestablished and the Centre was incorporated into DSIR Marine and Freshwater and then NIWA in 1992. My research and expertise has been in the areas of water chemistry, gas exchange across the air-water interface, contaminant chemistry, land use effects on water quality and diurnal changes in the physico-chemical properties of natural waters (viz., pH, dissolved oxygen and temperature).

4. I have published about 100 scientific papers and 70 technical reports, and have been on several scientific management groups. These include: the Tarawera River Technical Committee; Technical Manager for Tauranga Harbour Water Management Plan; the South Pacific Regional Environment Programme on marine pollution (SPREP POL); National Representative for Commission on Soil and Water Chemistry (International Union of Pure and Applied Chemistry (IUPAC); Waikato Branch President and Council Delegate, NZ Institute of Chemistry (NZIC); Advisory Committee member and Editor for ICEST 2007 conference, American Academy of Sciences, Houston Texas; and the National Freshwater Centre.

5. I have been actively conducting research on the influence of agriculture on water quality for more than 20 years. In 1995-97 I led a study specifically examining dairy farming

impacts on stream quality in the Waikato (the "Toenepi" study) that was the first to look solely at dairying impacts. Since 2001 I have led the water quality aspects of the Best Practice Dairying Catchments for Sustainable Growth project. This project (initially funded by the NZ dairy industry and now funded via the Foundation for Research, Science and Technology (FRST)) is an integrated catchment management study that involves industry, farmers, advisory and regulatory agencies (Dairy NZ, Ministry for the Environment (MfE) and regional councils) and science providers (NIWA and AgResearch) working in five dairying catchments in the Waikato, Taranaki, Canterbury, Southland and West Coast regions. The project identifies linkages between land use practices and water quality, and uses these to devise best management practices (BMPs) for each of the catchments, with their specific regional issues (eg. border-dyke irrigation in Canterbury, high stream-channel density in Taranaki). Water quality trend analysis, together with biological assessments of stream condition, is used to assess stream state in relation to the rate of adoption of BMPs, and the results are reported back to farmers at annual field days. Farmers in each of the catchments have identified key values for their respective streams and the associated downstream water bodies, and these have been coupled with farming activities via linkage diagrams derived at community meetings.

6. I am also involved with research programmes on restoration of aquatic ecosystems (RAE) and water allocation (WALLO). The RAE programme addresses the science underpinning restoration of lowland streams like those in dairy catchments. The WALLO programme has mainly been concerned with the effects of irrigation withdrawal on downstream water quality from contaminated return flows. Both research areas have an emphasis on nutrients (N and P forms), sediment, water clarity and faecal indicator organisms (viz., *E. coli*).

My role in the One Plan

7. I have had more than 30 years' experience with aspects of water quality standards and have been involved with several submissions regarding water classification and standards. I have extensive experience with land-water interaction, particularly as it applies to dairy farming in New Zealand, and with the development and design of best management practices (BMPs) to reduce adverse impacts of farming on waterways. It is on the basis of this background that I have been asked to present evidence for Horizons' One Plan Hearing.

8. I have reviewed reports prepared by Horizons Regional Council for the Proposed One Plan. These include a review of recommended water quality standards for the Manawatu-Wanganui Region (Ausseil and Clark, 2007) and nitrogen and phosphorus loads to rivers in the Manawatu-Wanganui Region: An analysis of low flow state (McArthur and Clark, 2007).

9. I have read and agree to comply with the Environment Court's practice note Expert Witnesses – Code of Conduct.

2. EXECUTIVE SUMMARY OF EVIDENCE

10. Outcomes from the Limiting Nutrients Workshop convened by Horizons Regional Council are summarised in paragraphs 33-46 and key findings are listed as follows:

11. Not all rivers and streams will require nutrient management to minimise unwanted periphyton blooms. Those with soft substrates, not discharging to lentic systems or coastal areas and with low macrophyte cover, are largely exempt from nutrient management. All others need some form of nutrient management.

12. Nutrient management is important for coastal waters and estuaries, where macroalgae and phytoplankton may be more of a problem than periphyton. Thus, it would be prudent to derive or use standards that prevent periphyton blooms in rivers and which also provide adequate protection for estuarine and coastal waters.

13. Both N and P need to be managed because of the interconnectivity of waterways (where different nutrients might be limiting in the same stream network).

14. Periphyton growth and vigour is determined by antecedent water quality. This affects periphyton recovery from major disturbance events (floods). Lengthy exposure to high concentrations of nutrients is likely to give rise to a vigorous growth of periphyton that will respond more quickly than if it had grown in low-nutrient waters. For this reason, year-round control of both N and P is important.

15. It is important to carry out N:P calculations or nutrient diffusing substrate (NDS) methods down a catchment with sites selected in relation to inflows, land use and point sources. If these are not known, about 3-4 sites should be selected.

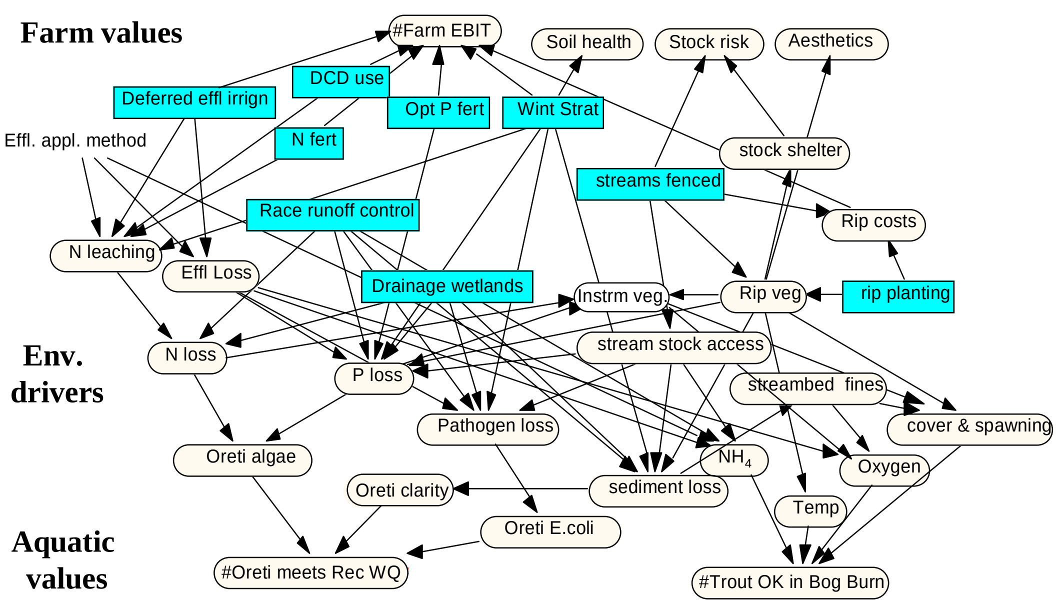
16. As a general rule, a reduction in concentration of a given limiting nutrient will reduce periphyton biomass. However, undesirable plant growths in waterways below point

source discharges are affected by many factors, including antecedent nutrient concentrations. It would be imprudent to rely solely on controlling one nutrient concentration (viz., P) as a management tool to prevent excessive periphyton growth, particularly when there are moderate to high concentrations of N.

17. Applying controls only to the "limiting" nutrient (and not the other nutrient) is not recommended (ie. only controlling P). Nutrient limitation for unwanted algae growth may vary spatially (eg. estuaries versus upland rivers) and temporally (ie. seasonally). Where there is a key indication of a single, limiting nutrient (eg. P), it would be sensible to focus on managing that nutrient without neglecting controls on the other macronutrient (eg. N).

18. Permitting a land use because it is mainly known for being the source of one (non-limiting) nutrient, rather than the targeted limiting nutrient, may unwittingly allow other forms of pollution (eg. faecal matter and sediment) to occur.

19. Community values: Linkage diagrams are an effective way of identifying community values for water bodies as a way of focusing interest and identifying the cause-effect linkages between activities on land, and the consequences for waterways. This is an effective way of getting community input to resource management issues and promoting an understanding of cause (eg. land uses) and effect (eg. degraded water quality) relationships. Linkage diagrams showing mitigation options have been useful in showing dairy farmers how BMPs practices work. An example is included here of a linkage diagram derived for dairy farmers in the Bog Burn catchment (central Southland).



20. I disagree with the suggestion put by Mr Hamill on behalf of Palmerston North City Council that the ammonia (NH_4) standard should apply to *average* values and vary according to pH, as set out in table 8.3.7 of the ANZECC (Australian and New Zealand Environment and Conservation Council) Guidelines, produced in 2000) water quality guidelines. The argument for varying the ammonia standard according to the ambient water pH seems impractical as dischargers would require reliable prior knowledge of pH to determine maximum ammonia loads. While this is not impossible, it seems unduly awkward, and has the potential for ammonia levels to be harmful if measurements of pH are wrong. Application of the ammonia standard to average ammonia concentrations has the potential for higher concentrations of ammonia in the lower Manawatu River and might be argued as being acceptable given that acute toxicities are also much higher than chronic toxicities. Operationally, this could be complicated to manage and to monitor, because it might require acute toxicity criteria to be invoked as well, as the chronic toxicity criterion (35 mg N/m^3) that is intended to protect most aquatic life.

21. Also with regard to Mr Hamill's evidence, regarding targeting ammonia standards for the freshwater clam (*Sphaerium novaeselandiae*) to rivers where it is known to be found, I consider that there is a need to have standards that are easily applied, provide protection for the designated water classification (in this instance, trout fishery or other significant fishery, TF3) and are soundly based. Having standards based on the presence/absence of certain species would add to the complexity of water resource management and potentially reduce the level of protection for aquatic life in the lower Manawatu River.

22. Faecal pollution of waterways increases the risk of disease transmission via waterborne pathogens. In addition, faecal pollution of waterways detracts from their recreational values and is considered by Māori to be a spiritual transgression and therefore, culturally unacceptable.

23. *Escherichia coli* (*E. coli*), found in the intestines of warm-blooded animals, is the preferred indicator organism for faecal pollution. The common strains of *E. coli* are not harmful but are simply used to indicate the presence of faecal pollution and to enable an assessment to be made of potential health risks that might arise from pathogens (eg. *Campylobacter jejuni*).

24. Best Management Practices for minimising faecal inputs from agricultural systems may be divided into those that reduce direct loadings from point sources to waterways and those that mitigate diffuse (non-point) source inputs, from pastoral agriculture in

particular. The major agricultural point sources of faecal pollution are dairy ponds discharging dairy shed effluent (DSE). BMPs for mitigating the effects dairy pond discharges to waterways include using land irrigation instead of ponds, the use of combined pond+irrigation systems to defer irrigation during wet weather until soils are dry enough for infiltration to occur, and advanced pond systems that separate the functions of simple two-stage ponds so that processes including micro-organism (bacteria, protozoa and viruses) die-off are optimised.

25. Diffuse sources of faecal pollution from agriculture include farm run-off (paddocks, farm laneways and tracks, and bridge and culvert crossings) and direct inputs from cattle crossing streams or grazing in riparian zones close to river banks. BMPs for mitigating diffuse sources include (i) avoiding grazing 'wet' soils in order to minimise run-off losses; (ii) maximising soil infiltration by the use of feed pads and other hard surfaces (wintering pads) in wet conditions to reduce soil compaction and overland flow. Dung and urine can be collected from these and treated separately (eg. via ponds, followed by land disposal); (iii) stock exclusion from waterways (as required in the Clean Streams Accord) via riparian fencing. This may be augmented with vegetated buffers that promote settling and trapping of faecal organisms on land, with subsequent die-off or predation by other micro-organisms; (iv) properly designed stream crossings with berm-and-trap systems to divert run-off away from streams onto paddocks; (v) deferral of irrigation when soils are saturated through use of holding facilities (ponds, sumps) and low application rates to soils to avoid 'short-circuiting' of effluent via soil cracks (macropores) to drainage networks; and (vi) more efficient irrigation systems that spread effluent uniformly and at loading rates that do not cause soil saturation.

Proposed One Plan reports reviewed

26. I have reviewed reports prepared by Horizons Regional Council for the Proposed One Plan. These include a review of recommended water quality standards for the Manawatu-Wanganui Region (Ausseil and Clark, 2007) and Nitrogen and phosphorus loads to rivers in the Manawatu-Wanganui Region: An analysis of low flow state (McArthur and Clark, 2007).

27. **The water quality standards document (Ausseil and Clark, 2007):** In my opinion the water quality standards chosen for Ecosystem Values are consistent with the literature and in my opinion, are reasonably based. Other standards derived in this report appear to be based on consultation with, or reference to, the best available experts and published scientific literature (see paragraphs 62-69 of this evidence).

28. I recommend that if a livestock water supply standard is specified in the One Plan that it be set at 550 *E. coli* /100 ml, the Action/Red value for contact recreation, so that both water quality values are protected.

29. My review of this report (Ausseil and Clark, 2007) concluded that it was soundly based and that the individual standards were derived in a scientific way using the available literature, taking into account local conditions in defined "water management zones" and the specific values to be protected.

30. I have reviewed the report on nitrogen and phosphorus loads to rivers in the Manawatu-Wanganui Region: An analysis of low flow state (McArthur and Clark, 2007) (paragraphs 70-71 of this evidence). The assumptions used by the authors in their analysis are carefully explained in section 3.3.2 of their report. In my view, the values of this report are (i) identifying areas where N and P levels exceed proposed water quality standards, and the key contributing sources in the major rivers of the Manawatu-Wanganui Region; (ii) giving an indication of the relative size and location of point source and non-point sources; and (iii) identifying where greater monitoring will be needed to enable more accurate calculation of river loads at low flows.

3. EVIDENCE

Limiting nutrients workshop

33. On 25 October 2006, Hawkes Bay and Horizons Regional Councils convened an experts workshop on "limiting nutrients for controlling undesirable periphyton growth" (Wilcock *et al.,* 2007), which had a direct relationship to the Proposed One Plan. I was a participant in that workshop along with Drs Biggs, Death, Hickey, Larned, and Quinn. A key question asked was, "if one nutrient element has been identified as limiting, do we need to manage the other?" Key outcomes of that workshop follow:

34. Not all rivers and streams will require nutrient management to minimise unwanted periphyton blooms. Those with soft substrates, not discharging to lentic systems or coastal areas (see evidence by Dr J. Zeldis) and with low macrophyte cover are largely exempt from nutrient management. All others need some form of nutrient management.

35. Although nutrient management is not necessary to control periphyton growth in soft-bottom streams, it is still a sound strategy for (i) reducing inputs to sediments that might otherwise stimulate unwanted macrophyte growth; (ii) managing downstream (hard-substrate) waters that might be subject to periphyton blooms; and (iii) avoiding

eutrophication problems in downstream environments such as lakes, estuaries and coastal waters.

36. Nutrient management is important for coastal waters and estuaries, where macroalgae and phytoplankton may be more of a problem than periphyton. Thus, it would be prudent to derive or use standards that prevent periphyton blooms in rivers while also providing adequate protection for estuarine and coastal waters. Dr Zeldis covers the matter of nutrient concentrations, and their effects on undesirable plant growth in coastal and estuarine waters, extensively in his evidence.

37. Both N and P need to be managed because of the interconnectivity of waterways (where different nutrients might be limiting in the same stream network). For example, monitoring of the upper Manawatu River (above the Hopelands site) during the 2007-2008 summer by Horizons Regional Council (Roygard and McArthur, 2008, p35) showed that dissolved reactive phosphorus (DRP) concentrations were much higher than normal, whereas soluble inorganic nitrogen (SIN) concentrations were extremely low, and limiting. Previous monitoring had established that in the upper Manawatu River, P limitation was normal during summer.

38. Periphyton growth and vigour is determined by antecedent water quality. This affects periphyton recovery from major disturbance events (floods). Lengthy exposure to high concentrations of nutrients is likely to give rise to a vigorous growth of periphyton that will respond more quickly than if it had grown in low-nutrient waters. For this reason, year-round control of *both* N and P is important.

39. The most rigorous method for assessing periphyton response to nutrients is to conduct nutrient diffusing substrate (NDS) assays, but the soluble N:P ratio offers a useful tool for exploring the potential for one nutrient to be identified as limiting growth and to predict the likelihood of periphyton blooms.

40. Other means for assessing the risk of periphyton blooms include ratios of PC/PN (or %PN) and PC/PP (or %PP) of algal biomass, but care needs to be taken to avoid confounding results caused by entrained particulate material within the periphyton matrix biasing the PN/PC and P/C ratios. Bioassays can also be used to investigate nutrient limitation and are generally considered the “gold standard” against which other methods are assessed.

41. It is important to carry out N:P calculations or NDS methods down a catchment with sites selected in relation to inflows, land use and point sources. If these are not known, about 3-4 sites should be selected.

42. As a general rule, a reduction in concentration of a given limiting nutrient will reduce periphyton biomass. There are few reported observations of this happening for diffuse source inputs of nutrients but there is supporting literature where point source inputs have been reduced. However, undesirable plant growths in waterways below point source discharges are affected by many factors, including antecedent nutrient concentrations. It would be imprudent to rely solely on controlling one nutrient concentration (viz., P) as a management tool to prevent excessive periphyton growth, particularly when there are moderate to high concentrations of N. In at least one instance, reducing P from a point source discharge (11 March 2009 Horizons memorandum concerning Feilding STP periphyton monitoring results, K. McArthur) below what is deemed to be a limiting concentration did not inhibit periphyton growth.

43. Applying controls only to the “limiting” nutrient (and not the other nutrient) (ie. only controlling P) is not recommended. Nutrient limitation for unwanted algae growth may vary spatially (eg. estuaries versus upland rivers) and temporally (ie. seasonally). Where there is a key indication of a single, limiting nutrient (eg. P), it would be sensible to focus on managing that nutrient without neglecting controls on the other macronutrient (eg. N).

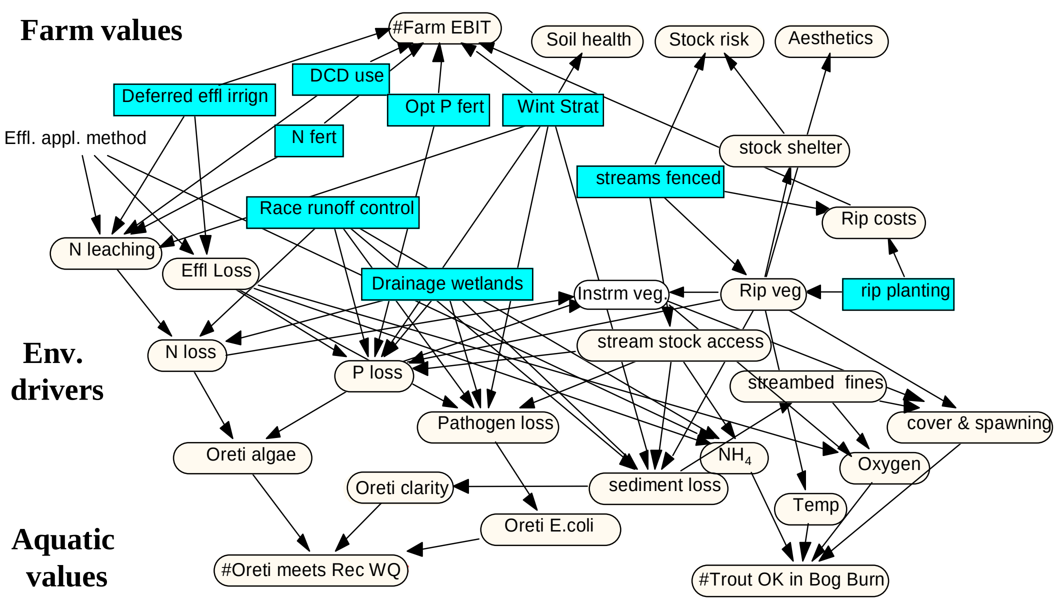
44. Permitting a land use because it is mainly known for being the source of one (non-limiting) nutrient, rather than the targeted limiting nutrient, may unwittingly allow other forms of pollution (eg. faecal matter and sediment) to occur.

46. With regard to periphyton response to the rate of nutrient supply: algae in fast-flowing, nutrient-poor water can grow as fast as algae in slow-flowing, nutrient-rich water. This is because algae are responding to a nutrient flux (ie. the product of concentration X flow) so that high flow X low concentration may equate with low flow X high concentration.

Community values

47. Dr Quinn and I have had experience in identifying community values for water bodies as a way of focusing interest and identifying the cause-effect linkages between activities on land, and the consequences for waterways. This is an effective way of getting community input to resource management issues and promoting an understanding of cause (eg. land uses) and effect (eg. degraded water quality) relationships. Linkage

diagrams showing mitigation options have been useful in showing dairy farmers how BMPs practices work. An example is included here of a linkage diagram derived for dairy farmers in the Bog Burn catchment (central Southland). At this meeting farmers, regional council staff, dairy farm advisors, agricultural and aquatic scientists, and representatives of Fish and Game and the Department of Conservation identified: (i) waterway values (ii) water quality and habitat targets needed to protect these values; (iii) on-farm practices that influenced these targets and values; and (iv) management options to produce any necessary reductions in farming pressures on waterways. The upper level of the diagram lists farmers' values (eg. security of income, soil and stock health) whereas the bottom level indicates the community values for the local stream (Bog Burn) and the major river that it flows into (the Oreti River). The intermediate layers of the diagram show farm actions and consequences (identifying particular pollutants and pathways between the land and water). The blue boxes are best management practices (BMPs) identified by agricultural and environmental scientists that can intercept these pathways and mitigate inputs to waterways (Quinn, personal communication, 2009).



48. Key water quality parameters that describe the condition of waterways and are diagnostic tools are outlined in Dr Quinn's evidence (viz., pH, temperature, dissolved oxygen, BOD, POM, QMCI, ammonia, other toxins, turbidity and clarity). In addition to these, I would add total nitrogen and phosphorus, dissolved reactive phosphorus and faecal indicator organisms.

49. Dr Quinn has addressed some of these in his evidence, with the exceptions of pH, ammonia, turbidity and water clarity, and other toxins. In my evidence I address pH, ammonia and other toxins, and Dr Davies-Colley deals with water clarity, turbidity and faecal indicator bacteria in his evidence.

50. pH is defined as the $-\log_{10}$ of the hydrogen ion activity and is a measure of how acidic, neutral or alkaline a given water body is at the time of measurement. Natural freshwater pH values in NZ are commonly in the range 6.3-8.5 (Wilcock and Nagels, 2001) and show greatest 24-hour (diurnal) variation in streams with high plant biomass, ie. macrophytes, phytoplankton and periphyton (Wilcock and Nagels, 2001), where ranges up to 6-10 have been observed (Close and Davies-Colley, 1990). Strong diurnal cycles of pH occur together as a result of the uptake and release of oxygen and carbon dioxide by aquatic plants. Maximum values of pH and dissolved oxygen occur in the late afternoon, as a result of photosynthetic production, whereas minima occur in early morning when respiration dominates (Wilcock and Chapra, 2005). pH is sometimes described as a 'master variable' because it affects the form of many charged chemicals (ions) in water. Ammonia is a common component of effluent treatment systems, such as dairy shed effluent ponds and community sewage systems, where concentrations of up to 100 mg N/L (g N/m^3) may be released into receiving waters before subsequently being diluted. In water, ammonia exists in ionised and un-ionised forms. Ammonia toxicity is strongly affected by pH: the higher the pH the greater the proportion of the toxic (un-ionised, or 'free') form (NH_3). Lower pH favours the formation of the comparatively non-toxic (ionized) ammonium form (NH_4^+). For example, at pH 9 and a water temperature of 20°C, the toxic NH_3 form comprises 28% of total ammonia, whereas at pH 8 and 20°C it comprises just 4% of total ammonia. It is worth noting that water laboratories, in general, analyse for combined (free plus ionized) forms and commonly use the symbol NH_4-N to denote 'total ammoniacal N'.

51. Evidence presented by Mr Keith Hamill on behalf of Palmerston North City Council (PNCC) recommends that for the Lower Manawatu Mana_11a subzone the ammonia (NH_4) standard should apply to *average* values and vary according to pH as set out in Table 8.3.7 of the ANZECC (2000) water quality guidelines. The current requirement of the Proposed One Plan for the Mana_11a subzone that ammonia nitrogen be less than 400 mg N/m^3 is based upon the ANZECC (2000) guideline of a maximum un-ionised ammonia concentration of 35 mg N/m^3 (similar to the US Environmental Protection Agency (EPA) 1999 criterion for protection of salmonid species in freshwaters with pH not less than 8 and temperature of 15°C). The report (Ausseil and Clark, 2007) states that "the inclusion of pH and temperature dependency leads to a recommended

standard of 400 mg NH_4-N/m^3 (expressed as total ammonia nitrogen) for TF2 and TF3 waters." Natural variations of pH in the lower Manawatu River subzone Mana_11a (classified HM/TF3) for the Opiki site are summarised from data over the 1997-2007 period (Ausseil and Clark, 2007) and are in the range 7.4-8.8. Diurnal measurements of pH would doubtless cause the minimum value to be lowered because of respiration, where the lowest pH values occur in the evening or early morning. Maximum pH values, generally occurring in mid-late afternoon, are likely to have been captured by monitoring. The argument for varying the ammonia standard according to the ambient water pH seems impractical as dischargers would require reliable prior knowledge of pH to determine maximum ammonia loads. While this is not impossible, it seems unduly awkward, with the potential for ammonia levels being harmful if measurements of pH are wrong. Application of the ammonia standard to average ammonia concentrations has the potential for higher concentrations of ammonia in the lower Manawatu River and might be argued as being acceptable, given that acute toxicities are also much higher than chronic toxicities (USEPA, 1999). Operationally, this could be complicated to manage and to monitor, because it might require acute toxicity criteria to be invoked as well as the chronic toxicity criterion (35 mg N/m^3) that is intended to protect most aquatic life.

52. Mr Hamill says that "Water quality standards for total ammonia have been set to protect 99% of species on the basis of the freshwater clam (*Sphaerium novaeselandiae*) being common in lowland rivers (Ausseil and Clark, 2007), but this stricter target is being applied to rivers where *S. novaeselandiae* does not appear to be present – resulting in overly strict water quality standards. A simple alternative to allow better targeting of water quality conditions would be to specifically identify *S. novaeselandiae* as a specific value in rivers where it is present (perhaps as 'biodiversity value') and apply more strict standards only to these streams. Alternatively, a 'do not deteriorate policy' may be adequate to protect the biodiversity value of *S. novaeselandiae."* In my opinion, there is a need to have standards that are easily applied, provide protection for the designated water classification (in this instance, trout fishery or other significant fishery, TF3) and are soundly based. Having standards based on the presence/absence of certain species would add to the complexity of water resource management and potentially reduce the level of protection for aquatic life in the lower Manawatu River.

53. pH affects the speciation (chemical form) of toxic substances, such as arsenic, phenol and heavy metals (viz., zinc, lead) but these are not generally considered a serious risk within Horizons' Region. Nonetheless, aquatic ecosystem protection from toxic substances is afforded by the water quality standards in Schedule D of the Proposed

One Plan. The standards are trigger values for toxicants at given percentile levels of protection, as specified in Table 3.4.1 of the ANZECC (2000) guidelines. For example, the ANZECC trigger value for protection of 95% of freshwater aquatic species from zinc is 8 $\mu g\ L^{-1}$.

54. The ANZECC (2000) guidelines are aimed at long-term protection of water quality resources and takes into account geographical location, water resource values (eg. aquatic ecosystems, recreation and aesthetics, and primary industry usage) and characteristics (eg. upland or lowland). The water quality guidelines incorporate current scientific, national and international information, and endeavour to promote a more holistic approach to aquatic ecosystem management. The ANZECC (2000) guidelines give trigger values for toxic substances (toxicants) that were derived using a statistical distribution approach that is based on a "probability distribution of aquatic end-points". This approach uses all the available dose-response toxicity data to obtain probability distributions, and attempts to protect a pre-determined percentage of species, usually 95%. Trigger values represent levels of protection for ecosystems and are given for 99%, 95%, 90% and 80% protection levels (ie. the percentage of species expected to be protected). In most cases, the 95% protection level trigger value applies to ecosystems classified as being slightly–moderately disturbed. The higher (99%) value is applied either for protection of ecosystems with a high conservation value, or as a default where there might be insufficient information about the properties of a particular toxicant (eg. bioaccumulation potential). Less stringent trigger values may be relevant for degraded ecosystems, possibly as an interim measure for subsequent water quality improvement. The ANZECC (2000) guidelines are widely accepted as the most rational first-approach method for protecting water quality values, especially from inputs of contaminants. By integrating the level of species protection they offer a more holistic approach than the traditional method based on toxicity data for particular species.

Faecal pollution

55. Faecal pollution of waterways increases the risk of disease transmission via waterborne pathogens. In addition, faecal pollution of waterways detracts from their recreational values and is considered by Māori to be a spiritual transgression and therefore, culturally unacceptable.

56. Faecal coliform were previously used as an indicator of faecal pollution of waterways. However, not all faecal coliform originate in faeces (notably *Enterobacter*, *Klebsiella*, and *Citrobacter*). For this reason, *E. coli*, found in the intestines of warm-blooded

animals, is the preferred indicator organism for faecal pollution (ANZECC, 2000). The common strains of *E. coli* are not harmf,ul but are simply used to indicate the presence of faecal pollution and to enable an assessment to be made of potential health risks that might arise from pathogens (eg. *Campylobacter jejuni*). Dr Davies-Colley addresses aspects of microbial contaminants in his evidence.

57. BMPs for minimising faecal inputs from agricultural systems may be divided into those that reduce direct loadings from point sources to waterways and those that mitigate diffuse (non-point) source inputs, from pastoral agriculture in particular.

58. In the past, the main point sources of faecal pollution to New Zealand rivers have been discharges of community sewage effluent, and discharges from dairy factories and meat works. These are regulated by discharge consents.

59. The major agricultural point sources of faecal pollution are dairy ponds discharging dairy shed effluent (DSE). Dr Jon Roygard will describe the significance of DSE discharges in Horizons' Region, in his evidence. DSE discharges are dealt with by discharge consents and there are many BMPs that can reduce their impacts on rivers and streams. These include using land irrigation instead of ponds, the use of combined pond+irrigation systems to defer irrigation during wet weather until soils are dry enough for infiltration to occur, and advanced pond systems that separate the functions of simple two-stage ponds so that processes, including micro-organism (bacteria, protozoa and viruses) die-off is optimised (Craggs *et al.,* 2003).

60. The more difficult challenge is in reducing diffuse source inputs of faecal matter, from run-off (paddocks, farm laneways and tracks, and bridge and culvert crossings) and from direct inputs deriving from cattle crossing streams or grazing in riparian zones close to river banks. BMPs developed for intercepting and diverting faecal run-off to waterways is covered in the evidence of Drs Davies-Colley and Monaghan. Briefly, these include: (i) avoiding grazing 'wet' soils in order to minimise run-off losses; (ii) maximizing soil infiltration by the use of feed pads and other hard surfaces (wintering pads) in wet conditions to reduce soil compaction and overland flow. Dung and urine can be collected from these and treated separately (eg. via ponds, followed by land disposal); (iii) stock exclusion from waterways (as required in the Clean Streams Accord) via riparian fencing. This may be augmented with vegetated buffers that promote settling and trapping of faecal organisms on land, with subsequent die-off or predation by other micro-organisms; (iv) properly designed stream crossings with berm-and-trap systems to divert run-off away from streams onto paddocks; (v) deferral of irrigation when soils are

saturated through use of holding facilities (ponds, sumps) and low application rates to soils to avoid ‘short-circuiting’ of effluent via soil cracks (macropores) to drainage networks; and (vi) more efficient irrigation systems that spread effluent uniformly and at loading rates less that do not cause soil saturation.

One Plan reports reviewed

61. I have reviewed reports prepared by Horizons Regional Council for the Proposed One Plan. These include a review of recommended water quality standards for the Manawatu-Wanganui region (Ausseil and Clark, 2007) and Nitrogen and Phosphorus loads to rivers in the Manawatu-Wanganui Region: An analysis of low flow state (McArthur and Clark, 2007).

62. The water quality standards document (Ausseil and Clark, 2007) describes the rationale for selection of standards for the Proposed One Plan. The process adopted was to firstly identify water body values (23 in total) that reflected community aspirations. These are broadly grouped into Ecosystem values (5), Recreational and Cultural values (9), Consumptive Use values (4), and Social and Economic values (5). Secondly, water quality standards were derived for the purpose of protecting the water body values. Lastly, water quality standards were applied to water bodies, taking into account all the values ascribed to them. Where a water body had more than one value ascribed to it, the most stringent numerical standard was selected in order to confer protection on all the values associated with the water body. A detailed account of the process is given in Ausseil and Clark (2007). Dr Quinn is commenting on the suitability of the numerical values of the standards in his evidence.

63. Ecosystems Values: Literature values for tolerances and preference levels of physico-chemical variables were reviewed for New Zealand native fish and macroinvertebrate species. In addition to these data, ANZECC (2000) guidelines were also taken into account in setting water quality standards for values groups in specific geological sub-zones of Horizons’ Region. For these reasons, the water quality standards chosen are consistent with the literature and in my opinion, are reasonably based.

64. Recreational and Cultural Values: Many of the values were not linked with water quality or water quality standards. Contact recreation standards took into account the ANZECC (2000) guidelines and current MfE (2002) guidelines for bathing water quality, with acceptable bathing water being when median *E. coli* concentrations are not greater than 260/100 mL. This is somewhat more stringent than the MfE (2002) guideline which calls

for additional sampling when the ‘Amber Alert” value (550 *E. coli* /100mL) is breached. A summary of the Proposed One Plan freshwater contact recreation standards is given in the table that follows.

Table 1. Microbial standards for freshwater contact recreation in the Proposed One Plan. *E. coli*/100 mL

Bathing season (1 Nov-30 Apr)		**Other times (1 May-31 Oct)**	
Lake	River	Lake	River
260	260 when flow is not greater than median	550	550 when flow is not more than 3x median

65. The standard proposed in the Proposed One Plan for nuisance organisms is based on work by Biggs (2000) for the Life-Supporting Capacity class of Ecosystem Values. The values (50-200 mg chlorophyll *a*/m^2) have been indirectly endorsed in a paper by Suplee *et al.* (2009), who conducted an opinion survey in Montana “to ascertain if the public identifies a level of benthic (bottom-attached) river and stream algae that is undesirable for recreation”. For the public majority, mean benthic Chl *a* levels equal to or greater than 200 mg/m^2 were determined to be undesirable for recreation, whereas mean levels not greater than 150 mg Chl *a*/m^2 were found to be desirable. Proposed One Plan chlorophyll standards are 50 (for upland hard sedimentary geological regions), and 120-200 for other streams in Horizons’ Region. Other standards (viz., water clarity, pH, and other chemical contaminants) are consistent with the ANZECC (2000) guidelines.

66. Water quality standards for the protection of the trout fishery value focus on pH, temperature, DO and BOD, and water clarity. These standards draw upon established authorities (eg. US EPA and Dr John Hay, Cawthron Institute) and are soundly based. Other standards concern biological indicators, periphyton biomass, ammonia and other toxicants; they have similarly been drawn from authoritative experts (eg. Dr Barry Biggs on periphyton, ANZECC 2000) and take into account local conditions.

67. Water quality standards for livestock drinking water detailed in Ausseil and Clark (2007) follow those in the ANZECC (2000) guidelines (viz., a median of 100 faecal coliform/100 mL, and an 80th percentile of 400/100 mL). The current ANZECC guideline is a median of 100 FC/100 mL and is quite stringent. It would not easily be met by many natural waters in rural catchments. Furthermore, ‘faecal coliforms’ includes bacteria of non-faecal origin (viz., *Enterobacter*, *Klebsiella*, and *Citrobacter*) and most water quality laboratories analyse for E. *coli*, which is specifically from the gut of warm-blooded animals. Taranaki Regional Council has adopted a standard of 1000 *E. coli* /100 mL for

stock drinking water. The current green/amber/red contact recreation criteria (260/550 *E. coli* /100 mL) lies between these two and has the added advantage of spurring further investigation (see below from the MfE entitled Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas. I recommend that if a livestock water supply standard is specified in the One Plan, it be set at 550 *E. coli* /100 ml, the action/red value for contact recreation, so that both water quality values are protected.

Acceptable/Green Mode: No single sample greater than 260 *E. coli* /100 mL.

- Continue routine (eg. weekly) monitoring.

Alert/Amber Mode: Single sample greater than 260 *E. coli* /100 mL.

- Increase sampling to daily (initial samples will be used to confirm if a problem exists).
- Consult the Catchment Assessment Checklist (CAC) to assist in identifying possible location of sources of faecal contamination.
- Undertake a sanitary survey, and report on sources of contamination.

Action/Red Mode: Single sample greater than 550 *E. coli* /100 mL.

- Increase sampling frequency to daily (initial samples will be used to confirm if a problem exists).
- Consult the CAC to assist in identifying possible location of sources of faecal contamination.
- Undertake a sanitary survey, and report on sources of contamination.
- Erect warning signs.
- Inform public through the media that a public health problem exists.

68. Nutrient standards for rivers and streams are recommended in the Proposed One Plan mainly to prevent undesirable periphyton growth and are thereby related to periphyton biomass standards (50–200 mg/m^2 depending upon the local geology). The rational behind this derives from the Limiting Nutrients Workshop and has already been described (sections 10-23 of this evidence). Standards are based on soluble inorganic nitrogen (SIN) and dissolved reactive phosphorus (DRP). SIN is the sum of oxidised forms (most notably nitrate and, to a lesser extent, nitrite) and total ammoniacal N (NH_4-N). Standards for SIN and DRP apply at all flows under 3x the median flow (the threshold for flood flows) and derive from consultation with experts (viz., Dr Barry Biggs, NIWA) and the ANZECC 2000 guidelines, as well as taking into account assessment of the values in each management zone and the relevant periphyton standards to which

nutrient standards relate. Dr Biggs will address the derivation of these standards in his evidence. The ANZECC guidelines (default trigger values) are based on 80th percentile measurements in reference (ie. relatively uncontaminated) rivers. Default values were derived (by ANZECC) where there was insufficient information on ecological effects to determine an acceptable change from the reference condition. The choice of 80th percentile (eg. for nutrient standards) is arbitrary but conservative (ANZECC, 2000) and when default trigger values are exceeded, it is recommended by ANZECC that further work be done to refine specific guideline values. The Proposed One Plan generally follows Dr Biggs' recommendations, and downstream standards take precedence over upstream standards. Current water quality is taken into account when setting standards for specific water bodies. That aspect of the report is outside my experience and I have no comment to make on standards for specific waterways.

69. My review of the report by Ausseil and Clark (2007) concluded that it was soundly based and that the individual standards were derived in a scientific way using the available literature, while taking into account local conditions in defined "water management zones" and the specific values to be protected.

70. I reviewed the report on Nitrogen and phosphorus loads to rivers in the Manawatu-Wanganui Region: An analysis of low flow state (McArthur and Clark, 2007) in 2007. The report addresses monitoring records for SIN and DRP in Horizons' Region, focussing on sites where non-compliance with the Proposed One Plan water quality standards has occurred regularly, under low-flow conditions. The authors recommend a number of areas for further monitoring to better validate these results, and suggest changes to compliance and State of the Environment monitoring. The report concerns the following major rivers: Manawatu (and Oroua); Whanganui; Rangitikei; Whangaehu; and Owahanga Rivers. It addresses key point sources and non-point (diffuse) sources of pollution for monitoring purposes. The report identifies two flows to be representative of low flow conditions: (i) mean annual low flow (MALF); and (ii) half median flow (or 75th percentile flow) in rivers with regulated flow regimes such as the Tongariro Power Development (TPD). The report calculates river loads (mass/time) by multiplying concentration (of a given nutrient) X river flow, at key locations on rivers. Loads between sites were inferred from the differences between downstream and upstream mass-flows under conditions of stable river flow. It was assumed that point source discharges were constant over this period. The total load of nutrient present at any point of the catchment comprises a contribution from point sources (PS load) and a component from non-point sources (NPS load). Non-point source loads were determined as the net nutrient load

(calculated from the SOE monitoring data) minus the load derived from point sources, as shown in the following equation:

$$NPS\ load = Total\ load - PS\ load$$

71. River concentration data were “stratified” (grouped according to the flows they occurred at, in relation to the natural distribution of flows (percentile values) in each water body) and compared with Proposed One Plan standards. Differences in river loads have to take into account natural processes of assimilation and release (of nutrients), and simple upstream-downstream comparisons may be misleading unless treated judiciously. The assumptions used by the authors in their analysis are carefully explained in section 3.3.2 of their report. In my view, the values of this report are: (i) identifying areas where N and P levels exceed proposed water quality standards and the key contributing sources in the major rivers of Horizons’ Region; (ii) giving an *indication* of the relative size and location of point source and non-point sources; and (iii) identifying where more monitoring will be needed to enable more accurate calculation of river loads at low flows.

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APPENDIX

List of nitrogen (N) and phosphorus (P) variables determined in water quality monitoring investigations. Detection limits given are those for the NIWA, Hamilton, water quality laboratory and used for the National River Water Quality Network.

Variable	Symbol	Detection limit (mg/m^3 a.k.a. mg m^{-3})
Nitrate + Nitrite Nitrogen (also known as total oxidised nitrogen)	NO_3-N (NB this is sometimes shown as NO_X-N or NNN)	1
Ammonium Nitrogen (This is the sum of dissolved ionised ammonia, NH_3, and ionised ammonium, NH_4^+)	NH_4-N	1
Total Nitrogen	TN	10
Soluble Inorganic Nitrogen (This is the sum of nitrate-N and ammonia –N)	SIN	1
Total Organic Nitrogen (This is the difference between TN and SIN)	TON	10
Dissolved Reactive Phosphorus	DRP	1
Total Phosphorus	TP	1

Nutrients are chemical compounds that are necessary for normal plant growth and are divided loosely into macro- and micro-nutrients. Routine water quality monitoring records two groups of essential macro-nutrients.

The availability of readily assimilated forms of the nutrients nitrogen and phosphorus are commonly accepted as factors limiting aquatic plant growth. Anthropogenic activities increase the nutrient loading through the discharge of waste products, fertilisers and general storm-water run-off. Nutrient enrichment can result in a proliferation of algae and macrophytes in waterways, which potentially has a number of detrimental effects including:

(i) Choking waterways leading to reduced drainage capacity.
(ii) Loss of amenity values.
(iii) Physical habitat reduction.
(iv) Excessive fluctuations in dissolved oxygen and pH.
(v) Reduced suitability for stock watering or horticultural irrigation.

The adverse effects of elevated nitrate levels can be mitigated by the provision of riparian vegetation, providing sufficient shading to preclude or minimise instream plant growth. Riparian vegetation also provides a mechanism for intercepting contaminants by filtering direct run-off and uptake of nitrate from the soil at the ground-water interface. The proactive approach is to prevent or minimise the discharge of nutrient rich discharges into waterways. Nutrient levels entering waterways can be reduced by a number of land management options including:

(i) Limiting concentrations from point sources by consent conditions.

(ii) Requiring land application of wastes in a way that minimises subsequent input to streams.

(iii) Implementing land management techniques, such as riparian zone protection, to reduce diffuse input.

Ammonia

Ammoniacal nitrogen is a macro-nutrient but is considered in general water quality evaluations in terms of its toxicity to many aquatic animals.

Ammonia occurs in a number of waste products which, if discharged to the environment, can result in elevated ammonia levels. Ammonia is reported as a combination of un-ionised ammonia (NH_3) and the ammonium ion (NH_4^+); at normal pH values the latter form predominates. Un-ionised ammonia is the more toxic form to aquatic life. The toxicity of ammonia is very dependent on water temperature, salinity and pH (US EPA, 1999).

In catchments with intensive farming practices, ammonia rich wastewaters can come from several sources. Potential causes of diffuse input include rainfall on areas adjacent to waterways that have been grazed recently, spray irrigated with wastewater, or which have had fertilisers such as ammonia urea applied to them recently. Rural point sources include race run-off, oxidation pond discharges, silage leachate, or raw wastes when disposal systems break down or are not used as intended.

Nitrite

Nitrite is the intermediate step in the conversion of ammonia to nitrate. It is usually short-lived in the aquatic environment in the presence of oxygen and is therefore indicative of a source of nitrogenous waste in the immediate vicinity of the sampling site. It is intermediate in toxicity between ammonia and nitrate (US EPA, 1986).

Nitrate

Nitrate is the end product of the breakdown (oxidation) of ammonia through the intermediate step of nitrite by microbial decomposition. Water for use as potable supply is limited to 10 mg N/L on public health grounds. Nitrate concentrations less than 400 mg/L in livestock drinking water should not be harmful to animal health. Water containing more than 1500 mg/L is likely to be toxic to animals and should be avoided (ANZECC, 2000). (NB these guidelines are for 'nitrate'. To be converted to nitrate *nitrogen* the following conversion should be used.

1 mg/L nitrate-N – 4.43 mg/L nitrate

Sources of nitrate in aquatic systems are similar to those discussed for ammonia. Nitrate is poorly bound to the soil and is therefore highly mobile. It is readily leached into local groundwater systems, particularly under high rainfall events. In winter, when ground conditions become saturated, the capacity of the soil to assimilate waste is reduced, resulting in elevated nitrate levels in run-off.

Nitrate is an important plant nutrient (generally non-limiting) which, in conjunction with sufficient available phosphorus, can lead to proliferation of aquatic plants (algae and macrophytes). Respiration of aquatic plants at night can lead to reductions in dissolved oxygen to the point that other aquatic organisms may become stressed or killed. Photosynthetic activity of aquatic plants also leads to elevated stream pH, which effects the toxicity of other contaminants in the water, such as ammonia.

Total Nitrogen

Total nitrogen is the combination of nitrate, nitrite, ammonia and organic nitrogen; it is used to estimate the "bioavailable" fraction of nitrogen in waterways and, in conjunction with total phosphorus and chlorophyll *a* levels, to assess the trophic status of water bodies, particularly lakes.

Total Phosphorus

Total phosphorus is a measure of all the phosphorus present in the sample and includes the soluble (bioavailable) fraction that is adsorbed onto sediment particles and present in the form of algae and other organic matter.

Dissolved Reactive Phosphorus (soluble reactive phosphorus)

Dissolved reactive phosphorus (DRP) is considered to be the bioavailable fraction of phosphorus and is important as an indicator of water quality. It is frequently cited as the nutrient limiting the proliferation of algae and other aquatic plants in New Zealand waterways.