BEFORE THE HEARINGS PANEL

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

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SECTION 42A REPORT OF MR GRAHAM BURNLEY MCBRIDE

FOR THE WATER HEARING

ON BEHALF OF HORIZONS REGIONAL COUNCIL

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1. INTRODUCTION

My qualifications/experience

1. My name is Graham Burnley McBride. I am a Principal Scientist at the National Institute of Water and Atmospheric Research (NIWA), in Hamilton.

2. I hold a Bachelor of Science degree in mathematics (Victoria University, Wellington) and Master of Science degree (Water Resources) from the University of Newcastle-upon-Tyne, UK.

3. I have been an active researcher in water-related issues for 35 years and have published many scientific papers and a book on these matters. That book's title is *Using Statistical Methods for Water Quality Management: Issues, Problems and* Solutions (2005), published by Wiley Press, New York.

4. I am a Life Member of WaterNZ, and also hold membership of the New Zealand Hydrological Society, the New Zealand Statistical Association, the New Zealand Freshwater Sciences Society, the New Zealand Society for Risk Management, the Society for Risk Analysis (Australia & New Zealand), and the International Water Association. I received the 2008 Medal from the New Zealand Freshwater Sciences Society, for services in that field.

5. I have read the Environment Court’s practice note ‘Expert Witnesses – Code of Conduct’ and agree to comply with it.

6. I have made use of footnotes in this evidence to give technical elaborations of some statistical procedures and concepts.

My role in the Proposed One Plan

7. I was involved in early discussions with Horizons Regional Council staff, particularly Dr Olivier Ausseil, in 2005. These discussions considered methods for computing "catchment loads" for the proposed planning environment. Since then I have had no involvement in this work.

Scope of Evidence

8. Given my background and publication record, I have been requested by Kate McArthur of Horizons to provide some brief statistical background and context for statements made in the evidence of Dr Michael Scarsbrook, for Fonterra Co-operative Group Limited. Those statements particularly concern the discussion of recent trends in water quality, as discussed in his paragraphs 46–54. I have not provided any original evidence to the One Plan Water Hearings Panel and the scope of my evidence is limited to discussing points in the expert evidence provided by submitters, as detailed above.

9. In doing so I have consulted with my NIWA colleagues Drs Robert Davies-Colley and Deborah Ballantine, because they have recently completed a large water quality trend analysis for the whole of New Zealand.

2. EVIDENCE

10. In the next two brief sub-sections I first give some general contextual information for statistical trend analysis, and then respond in more detail to Dr Scarsbrook's evidence. I finish with a Conclusions section.

Setting the Context for Trend Analysis

11. The word "trend" is defined (if at all) in various ways. In general terms it refers to the tendency for the current sample result to continue a pattern seen in previous results.

12. However, "seasonality" also refers to some continuation of patterns seen in recent data.

13. Even when trends and seasonality are removed from the data (there are a number of ways to do this, such as taking "moving averages"), some lower level of residual persistence pattern can still be found in the data.[1] This may be expected in situations where there are differences in water "residence times" in catchments — between streams, lakes and groundwaters. This feature is known as "serial correlation" or "autocorrelation" (ie. the tendency of today's result to be influenced by the previous results). Systems with "long memories" that tend to exhibit this feature are lakes and especially groundwater.

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1 Moving average techniques are in prospect when one hears news media reports of such things as "seasonally adjusted unemployment rates".

14. Modern trend analysis methods take account of seasonality and a number of other features of water quality data, such as missing values, the role of floods in modifying concentrations, and climate change effects[2], that would otherwise make it more difficult to discern trends. A key point is that the period of record analysed should be "long enough" to be able to discern and account for seasonality and, if necessary, serial correlation. Trend analyses from short periods of data can be misleading.

15. Some advocate that serial correlation ought also to be accounted for in a trend analysis. In my book I have demonstrated that this is not necessary if one is interested only in making inferences about trends *within* the period of record, and not trying to either extrapolate beyond that period, or to make inferences about the processes occurring within that period. Others have also stated that view.[3] However, while including serial correlation is likely to enhance the ability to detect trends, methods for doing so are not routinely available.

16. Because of the tendency for data frequencies to exhibit considerable skewness,[4] it has become accepted internationally that "non-parametric" trend analysis methods should be used for water quality data.[5] These techniques essentially perform calculations on the ranks of data, rather than their magnitude; this makes the analysis less encumbered by difficult-to-satisfy assumptions such as the requirement that data be drawn from "normal" distributions.[6] Consequently, inferences are made about the trends in median values, rather than means.[7] In terms of "statistical power" (ie. the ability to detect trends), little is lost and much can be gained in this manner. Nevertheless, one should always consider which statistic — mean or median — is the most relevant.

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[2] Scarsbrook, M.R.; McBride, C.G.; McBride, G.B.; Bryers, G.G. (2003). Effects of climate variability on rivers: consequences for long term water quality datasets. *Journal of the American Water Resources Association 39(6)*: 1435–1447 [errata in vol. 40(2): 544].

[3] Ellis, J.C. (1989). Handbook on the Design and Interpretation of Monitoring Programmes. Report **NS 29**, Water Research Centre, Medmenham, England.
Loftis, J.C.; McBride, G.B.; Ellis, J.C. (1991). Considerations of scale in water quality monitoring and data analysis. *Water Resources Bulletin* **27**(2): 255–264.

[4] Skewed datasets exhibit very occasional values that are much higher than most or all of the rest of the data.

[5] "Non-parametric methods" are sometimes called by the more illuminating phrase "distribution-free methods". The parameters in question are those that describe a statistical distribution from which data are assumed to have been drawn — such as the true mean and true standard deviation of a normal distribution. In that case we would have a "parametric method". Methods that do not make such assumptions are therefore "distribution-free", or "non-parametric".

[6] As an example of ranks, consider a short record of dissolved reactive phosphorus (DRP) concentrations of: 5, 7, 9, 2, 12, 6, 15, 13 and 111 parts per billion (mg/m^3). In a non-parametric analysis these data would be replaced by their ranks, ie., 2, 4, 5, 1, 6, 3, 8, 7 and 9, respectively, and calculations would proceed using those ranks instead of the data values.

[7] The mean of the DRP numbers in the previous footnote is their sum divided by the number of them. That sum is 5 + 7 + 9 + 2 + 12 + 6 + 15 + 13 + 111 = 180 mg/m^3. So the mean is 180 divided by 9, which is 20 mg/m^3. The median is the middle-ranked value. So it is the datum with the 5th rank, ie., 9 mg/m^3. Herein is clear evidence of skewness: the mean is much higher than the median.

Comments on Dr Scarsbrook's Evidence

17. Dr Scarsbrook has presented an analysis of trends in a number of water quality variables collected monthly over the last 10 years, from a 20 year record, for a number of sites in Horizons' Region, including a graphical display for site WA8 (Manawatu at Teachers College) in NIWA's National River Water Quality Network (NRWQN).[8]

18. Having regard to my earlier comments, 10 years is an appropriate period of record upon which to perform trend analysis.

19. Dr Scarsbrook has used the non-parametric "seasonal Kendall Trend test" on flow-adjusted data, using the "Time Trends 2.0" software. I am familiar with all these techniques and I was involved in the development of the Time Trends software. Dr Scarsbrook's usage of them is appropriate. He has not explicitly sought to include possible climate change effects.

20. On balance, having regard to the "statistical sampling error"[9] I accept that there is evidence of decreasing trends in median nutrients at some sites in the Manawatu catchment, including site WA8 (Manawatu at Teachers College). From a perusal of Dr Scarsbrook's graph in his paragraph 49, that trend seems to be particularly evident over the last five years. Note that the highest value of dissolved reactive phosphorus (DRP) in that graph (ie. about 33 parts per billion) occurred within the last five years, yet the overall trend in that period is downward. That is because a non-parametric trend detection method has been used, based on the ranks of the data. So the median can decrease over time, even when extreme values magnify. Indeed, were this highest value to double — to 66 parts per billion (mg/m^3) — the overall trend would be unaffected. But if a parametric method had been used, a different result would have been obtained. It may even be possible to see an upward trend in means (from a parametric analysis, as defined in footnote[5]) but a downward trend in medians (from the non-parametric analysis).

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[8] While controls are being proposed for only a proportion of the land use upstream of this site — in particular, above the Manawatu Gorge — improvements in that land use could be argued to manifest in improving water quality conditions at this site.

[9] Called by some the slings and arrows of outrageous fortune. This recognises that sometimes, just by bad luck, one can obtain a pattern in the *data* we collect which does not accurately reflect a *true* pattern. This can especially be an issue in water quality studies, because the number of data we are able to collect is often small.

21. In that regard it should be noted that the standards proposed in the Proposed One Plan are in terms of annual averages (ie. means), not medians.[10] For example, a DRP standard of 10 parts per billion (mg/m^3) as an annual average is proposed for the lower Manawatu River. Accordingly, while Dr Scarsbrook's graph indicates that median DRP concentrations are trending back toward a value of 10 parts per billion — where they were 20 years ago — the annual mean value will be somewhat higher and has some way to go before attaining the standard.

22. It does seem plausible that this trend in median values could be the result of improved land management practices or the wide-scale removal of dairy effluent discharges from waterways; though a detailed analysis of such a cause-and-effect chain has not been sighted. I do make two provisos.

23. First, in his paragraph 46 he quotes Helen Marr's evidence that "most recent monitoring continues to show a trend in elevated nutrient levels from non-point sources". The word "trend" in this context is more correctly "pattern".

24. Last, while trends appear to be downward in certain rivers, they are coming from a rather high plateau — a condition of degraded water quality. For attainment of good environmental conditions, meeting environmental standards, such trends do need to continue, as foreshadowed in my paragraph 21. So a statement in Dr Scarsbrook's paragraph 54 — that the imperative for region-wide controls on diffuse nutrient inputs to streams has reduced — is not an inference I would support. In that regard I also note that in the recent trend analysis by Ballantine and Davies-Colley (2009),[11] decreasing soluble inorganic nitrogen trends were found at a reference site not influenced by modified land use — the Mangawhero River at DoC Headquarters. Those authors speculated that climate change could be a contributory cause, as is also generally recognised by Dr Scarsbrook (at paragraph 52 of his evidence). However, this was the only trend seen at reference sites.

3. CONCLUSIONS

25. My main conclusions can be stated as follows:

    (a) Modern trend analysis can account for seasonality, effects of floods, climate influences, data skewness, missing values and sampling errors.

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[10] Ausseil, O.; Clark, M. (2007). Recommended Water Quality Standards for the Manawatu-Wanganui Region: Technical Report to Support Policy Development. Report 2007/EXT/806, Horizons Regional Council: Tables 23 and 24. This was to make them relevant to apply to the periphyton model which was developed using annual mean rather than median nutrient concentrations.

[11] Ballantine, D.J.; Davies-Colley, R.J. (2009). Water Quality State and Trends in the Horizons region. NIWA Client Report HAM 2009-090 for Horizons Regional Council, June 2009. 47 p.

(b) The period of record should be long enough to account for these influences.

(c) Non-parametric trend analysis is the most appropriate for river water quality data.

(d) Considering all these issues, Dr Scarsbrook's use of trend analysis is appropriate, with the possible exception of accounting for climate change effects — given that there is some limited possibility that these could cause an improving trend (for nitrogen) at one reference site.

(e) Trends of decreasing median nutrients are apparent at some sites in the Manawatu area.

(f) Trends analysed use median nutrient concentrations, whereas mean concentrations appear to be higher.

(g) Detailed analyses of the cause-and-effect relationship between decreasing nutrient concentration and land use changes have not been undertaken.

(h) While trends appear to be downward, they are coming from a high level of degraded water quality.

(i) I do not support the statement of Dr Scarsbrook that this trend analysis implies that the need for nutrient controls from diffuse inputs is reduced.

Graham McBride

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